leadership, and diversifying and expanding post-graduate engineering education. The autonomy and academic ambience created in these campuses have attracted the best faculty and students from all over the world.

The IITs have earned worldwide fame due to the sincere efforts of faculty, students and administration. The IIT system is one of the major success stories of independent India and ranks amongst the topmost institutions in the world in all ranking system of educational institutions. Self renewing process through continuous assessment of educational facilities and curriculum has proved to be a successful system. But how far the IITs have succeeded in conducting research and development at internationally competitive levels and succeeded in producing engineers 'on par with the best in the world' are the most frequently raised questions which is subject to further study, as India still remains a low ranked country in terms of technological education and research. Current figure shows that about 40 percent of the IIT graduates leave the country for higher studies or better job opportunities. Only a small percentage of the IIT graduates join the engineering sector, teaching, or R&D sector in the country.

To review the work and progress of the IITs, the Government of India had appointed the following committees:

* Nayadumma Committee in 1984,
* U. R. Rao Committee in 2003, and
* Ramarao Committee in 2004.

The Ramarao Committee had highlighted several of the issues involved and made recommendations regarding governance, faculty matters, research enhancement, entrance exam, linkage with industry and funding policy, etc. For recruiting new faculty members, the IISc practices were considered more flexible system than the IITs. The committee made a comparison of the IITs and IISc practices in this regard and recommended that IISc system may be adopted by the IITs for faculty induction, assessment and promotion. The committees made several recommendations which are contradictory to each other and many are yet to be implemented.

Table 3 shows a comparative analysis for the research outputs of the Mechanical Engineering Department of different IITs and IISc, Bangalore compared to that of other foreign universities (based on publication record in the period 1993-2003)

Table 3.

Institute	Current faculty strength	No. of papers		Citations			Impact Factors		
		Total	Per faculty	Total	Per faculty	Per paper	Total	Per faculty	Per paper
IITB	46	71	1.54	381	8.28	5.34	40.09	0.87	0.56
IITD-ME	36	54	1.50	190	5.28	3.52	21.59	0.60	0.40
IITD-AM	24	44	1.83	315	13.12	7.16	24.11	0.88	0.55
IITK	35	164	4.69	731	20.89	4.45	82.65	2.36	0.50
IITKgP	43	97	2.26	503	11.68	5.18	2.56	0.54	0.54
IITM-ME	43	134	3.12	605	14.07	4.51	62.01	1.44	0.46
IITM-AM	18	89	4.94	353	19.11	3.97	54.85	3.05	0.62
IISc	29	196	6.76	873	30.10	4.45	159.50	5.50	0.81
Stanford University	61	1272	20.85	6952	113.80	5.46	-	-	-

3.2 National Institute of Technology (NIT)

During 1956-1960, Regional Engineering Colleges were established to cater to the projected growth of technical manpower in various states. Regional aspirations were given a vent. As per the Mashelkar Committee's (1998) recommendation, 17 Regional Engineering Colleges (RECs) were converted to National Institutes of Technology (NITs) in 2003, changing the entire pattern of funding and governance and the control was shifted from state to centre. Each of the NITs function autonomously sharing only the entrance tests between them. The autonomy in education enables the NITs to set up their own curriculum, thereby making it easier to adapt rapidly to the changes in industry requirements. Post upgradation, all the NITs have started showing great improvements in terms of student quality, administration structure, academic research, and student placements.

The reputation of NITs as centres of excellence has gained acceptance in industry as well as in academia, primarily because the standard of education and quality of NIT students has been consistently better than most other colleges in India. Various nationwide college surveys rate most of the NITs over other engineering colleges in India, except for the IITs and a few other institutions. NITs are again governed by a different act.

4.0 Polytechnic Education

Polytechnic represents a technical institution at the middle level which conducts full-time diploma courses in civil, mechanical and electrical engineering, etc.

After India got Independence in 1947, the Government recognised the importance of technical manpower for the economic development of the country and decided to expand facilities for technical education and technical training in a big way. In 1947, there were about 53 institutions conducting technician courses (diploma courses) with a total admission capacity of about 3,700 students per year; the total out-turn from these institutions was of the order of 1,500 per year. In 2008-09 the total number of polytechnics was approximately 1,300.

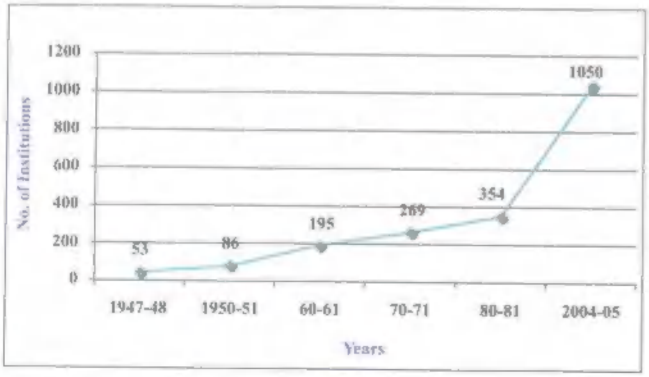

Fig 3: Growth of Polytechnic Institutions in India since 1947

During late sixties, there was severe criticism of polytechnic education in the country. The Government of India constituted a Special Committee under the Chairmanship of Prof. G. R. Damodaran in 1970 to examine the entire system of polytechnic education and to recommend measures for improving the practical content of diploma courses through cooperation between polytechnics and industry. The committee's recommendations helped the Government to concentrate on qualitative improvement through starting of diversified courses and sandwich programmes, review of curriculum, inclusion of experts from industry, and granting of autonomy to polytechnics.

Some problems of the polytechnic systems are: (i) courses are theory-based and their practical content is inadequate, and (ii) polytechnic institutions can only give diplomas and cannot offer degree programmes like other universities. In India, in many states, the number of degree holders now exceeds the number of diploma holders. The trend needs to be reversed. Also, skill-based training needs to be imparted.

5.0 Role of Private financing in Technical Education in India

During the 1980s, there was unparalleled demand for skilled manpower and quality higher education relevant to the needs of business and industry. In 1986, Rajiv Gandhi announced a new education policy, the National Policy on Education (NPE), which was intended to prepare India for the 21st century. The new policy was intended to raise educational standards and increase access to education. At the same time, it was to safeguard the values of secularism, socialism and equality, which had been promoted since Independence.

Another very important development of the early 1990s that had tremendous impact on higher education was the introduction of new economic reform policies that included stabilisation and structural adjustment, which required a drastic cut in public expenditures in education. In fact, these policies set the tone for strong reforms in higher education in India in the following years and on the whole, higher education suffered severely. Public expenditure on higher education began to decline since the beginning of the 1990s.

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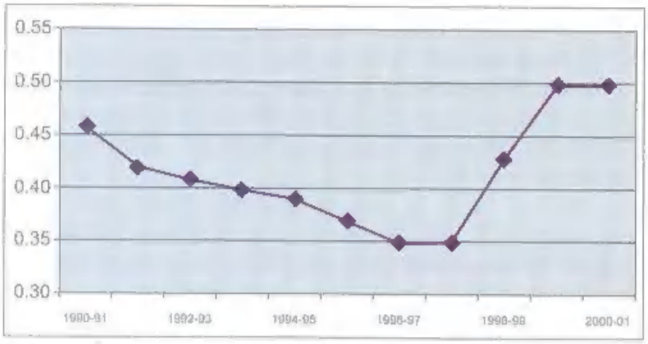

Fig. 4: Declining Share of Higher Education in GNP (Per cent)

[Source: Tilak, Jandhyala B G, 2003]

The demand for technical education has grown far more rapidly than what public institutions can accommodate, and the Government finances were inadequate to meet the growing demand. With the initiation of the new economic reform policies, reducing budget for higher education, increasing purchasing capacity of middle class people, and the paradigm shift of Government towards primary and secondary education, a large number of private institutions and deemed universities came up, which led to imbalance in the quality of the technical education. Professional education expanded along with private education sector. Table 4 shows how engineering education has grown rapidly over the past 9-10 years.

Table 4: Growth of engineering colleges in India

Type	1947	1960	1970	1980	1990	2000	2006
Government and aided	42	111	135	142	164	202	212
Unaided	2	3	4	15	145	467	1299
Total	**44**	**114**	**139**	**157**	**309**	**669**	**1511**

The issue of private sector initiative in education sector has been a matter of great controversy and debate in India. According to the projection made by NASSCOM, the manpower requirement in IT enabled services alone was expected to grow rapidly to about 1 million by 2007 and by 2012 India is supposed to actually face a shortage of trained manpower in the sector. However, exhaustive manpower analysis needs to be done, for a follow up of this conclusion. Global recession has added to the confusion.

To meet the need of a much larger number of good institutions of engineering and technology, private initiative have an important role to provide opportunities for technical education to a much larger number of students, since this national need cannot be fulfilled by public funding alone. But the regulatory authorities like UGC and AICTE should try to ensure that this massive expansion does not dilute its efforts at supporting excellence and quality. Proper regulatory framework is needed for the private sector, in terms of their fees, admission process, teaching and learning process, and governance, to ensure the quality of higher education and also equity.

6.0 Curriculum & Quality Assurance in Technical Education

The core of technical education is the curriculum, which is not only need-specific but to some extent, also country/region-specific. Initially, the practical training for engineering education was imparted in factories – which later were transferred to laboratories and workshops. In India, AICTE has recently devised a new curriculum framework which includes the desired percentage of science, humanities, engineering science, core/professional subjects, design/project, laboratory, workshop class, etc. This is to allow cross-border movement of technologists and also for India being a provisional signatory of the Washington Accord.

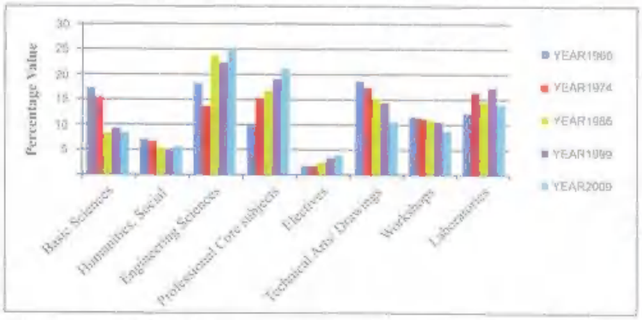

Fig. 5: Variation in the areas from the year 1966-2009 in the Mechanical Engineering curriculum.

A comparative analysis of the changing trends in the curriculum has been done for the mechanical engineering at first. The analysis shows the following patterns, which can be used for curriculum design in our country.

1. The numbers of periods allotted to professional core subjects have witnessed a steady increase over the past 50 years as depicted by Figure 5. The percentage of periods allotted to this field has increased from 1966 to 2009. This significant increase has been necessitated due to developments in the field of mechanical engineering into newer areas of energy, manufacturing and interdisciplinary areas as robotics, biomechanics, etc. Also, more stress has been put on fluid machinery, manufacturing technology, and advanced computational techniques such as finite element methods. But this increase has been done at the cost of technical arts/engineering drawing, workshop classes.

2. The contribution of technical arts/drawings to the mechanical engineering curriculum framework was 18.98%, as obtained from the 1966 period allotment. But this has seen a remarkable drop since then and has decreased to just 11.03% in 2009. This shows less emphasis on hands-on drawings over the period of time. The reason might be the perceived notion of lesser employment of students in consultancy organisations and advent of computerised drawing. The effect is yet to be observed because many of the engineering subjects, particularly engineering mechanics, need a very good conceptual understanding of the physical system which needs good concept of technical arts/drawings.

3. Another significant change can be observed in the period allocation to workshops. The percentage of workshops held during 1966 has dropped steadily from 12.03% to 9.19% in the year 2009, a decrease of 2.84% (Figure 5). This strengthens the report by NASSCOM which says that 75% of engineers in India are unemployable, citing 'more thrust on academics and theory' as the reason. Engineering (or for that matter technology) relates to practical applications. So there is a contradiction here that needs to be resolved, even keeping in mind that the growth of the mechanical engineering discipline has been explosive.

4. The percentage of elective period allocation has seen a steady rise from 2.14% in 1966 by 2.27% to 4.41% in 2009. This can be related to the point raised in the earlier conclusion that the students need to have core knowledge of the discipline. The specialised areas can be covered by electives (optional) which can be chosen by the student depending on his/her aptitude, as well as the requirement at that point of time of the industry. It must be clearly noted here that the need of industry varies with time. To meet the outsourcing requirements of software management from some countries, engineering graduates were needed. But with the development of climate change issues and the thrust on biomedical solutions, the number of electives have been increased, as some of the following names suggest-solar energy, aerodynamics, computer aided design and manufacturing, biomechanics and biomaterials, advanced dynamics and vibration, design of thermal systems, etc.

5. The percentage of humanities had decreased till the late 1990s from 7.45 in 1966 to 5.67 in 1986, but tends to show a gradual increase in the recent years from 5.34% in 1999 to 5.88% in 2009. World over, all the accrediting agencies are talking about the need of engineers having more communication skills, knowledge of economics, ideas of professional ethics, etc. So all the latest guidelines including ABET, Bologna, or India's AICTE suggest percentage increase in humanities courses. To incorporate this, some sacrifice may have to be made at other areas and that is yet to be agreed upon unanimously.

6. The percentage of engineering science has not undergone drastic changes, although the data reveals an increase of 6.28% in recent years when compared with the 1966 index. This shows the trend has been towards increasing the percentage of engineering sciences in curriculum framework in order to instil in the student's mind a sound pedagogic system which aims at providing them with a clear concept of engineering at the beginning of the learning stage itself and strengthen their foundation to enhance their capability of understanding when they deal with professional core subjects and electives.

7. Basic sciences are responsible for generating fundamental thinking ability in students. An analysis of the percentage of basic sciences over the years shows a steep decline from the year 1986 onwards. This remarkable drop is indicative of the fact that during the early 1970s the courses were based on a five-year duration which led to the introduction of calculus-based science subjects like physics, chemistry as well as mathematics to a much deeper extent than what they are in the present four-year curriculum.

Regular institute-industry interaction, which is critical to restructure the curriculum with the changing needs of the industry, is missing in India. Engineering institutions must interact and collaborate with the industries, for mutual benefit. Students benefit greatly from practical experience gained during summer job

or project work in industry – in terms of gaining practical knowledge. Engineering education faculty and administrators, and the programs that they offer, benefit greatly for guidance given by industry advisory groups. Industry also often provides direct support to engineering institutions, through funded research projects, equipment grants, sabbatical opportunities for faculty, etc. Industrial feedback is a must for any curriculum framework, which is absent in most of the education institutions in India. This has to be rectified and curriculum should be updated to meet the needs of the 21st century and make the students aware of local and global needs.

An analysis of curriculum of ranked institutions show that higher emphasis on engineering sciences and interdisciplinary subjects give rise to higher research output and better ranking in which our system is lacking.

In India, the AICTE has established National Board of Accreditation (NBA) in 1994 for quality assurance of technical institutions on the basis of guidelines, norms and standards laid down by it. Now, India being a signatory of the Washington Accord has to satisfy all of the following criteria for accrediting engineering programmes measured in terms of student outcome.

The program must have documented student outcomes that prepare graduates to attain the program educational objectives. Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program.

(a) An ability to apply knowledge of mathematics, science, and engineering

(b) An ability to design and conduct experiments, as well as to analyse and interpret data

(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) An ability to function on multidisciplinary teams

(e) An ability to identify, formulate, and solve engineering problems

(f) An understanding of professional and ethical responsibility

(g) An ability to communicate effectively

(h) A broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(i) A recognition of the need for, and an ability to engage in life-long learning

(j) A knowledge of contemporary issues

(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

[Source:
ABET website http://www.abet.org/forms.shtml
accessed on 16.03.11]

For such student outcomes, experienced and quality faculties are a must. Quality improvement programme for faculties need to be mandatory. In most countries in the world, the function of educational accreditation is conducted by a government organisation, such as a ministry of education. In the United States, however, the quality assurance process is independent of government and is performed by private membership associations. In India, the umbrella organisation is the NBA, which now has been made a registered society. In most of the countries the assistance of professional societies has been incorporated, but not in India. Quality assurance systems can be improved to raise technical education to world standard by strictly following a professional, transparent and nationally suitable model involving faculty members of the highest standard.

At present, the institutions cannot compete with the best unless they improve the quality of both teaching and research. They should initiate steps to increase enrolment at the post-graduate and research levels and to make strategic investment in research to have a comparative advantage in the global market.

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Stone Technology in India

K. Paddayya

Introduction

Rock and water, representing the hard and soft components of the planet earth, form the basis of all organic life including the human species. The findings of prehistoric archaeology from Omo and Gona valleys of Ethiopia reveal that man's utilization of stone for making artefacts has an antiquity of 2.5 million years (Fig.1).

Fig. 1. 2.5 million-year-old stone artefacts (chopper and flakes) from Omo and Hadar valleys in Ethiopia.

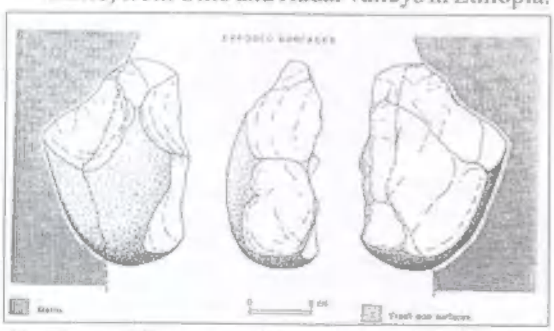

Fig. 2. Two-million-year-old stone artefact (core) from Riwat in Pakistan.

The discoveries at Riwat near Peshawar (Fig.2) and Uttarbaini in Jammu show that tool-making traditions began two million years ago in the Indian subcontinent. Such findings are used by archaeologists to define man as the tool-maker. This essay seeks to present an overview of man's use of stone in India across ages for catering to his material, emotional or religious, and aesthetic military needs.

Stoutly opposing the long-entrenched Biblical view of the origin of world and man in 4004 B.C., Charless Lyell argued that the various rock formations we see on the earth formed one after the other over a long period of time due to natural processes such as volcanism, erosion and deposition which are still active. He thus founded the discipline of geology and published his three-volume book entitled *The Principles of Geology* between 1830 and 1833. Geologists group rock formations into three major types on the basis of natural processes which led to their formation. These are a) volcanic rocks like basalts and granites resulting from outpouring and cooling of magma; b) sedimentary rocks like shales, limestones and sandstones resulting from deposition and hardening of soft sediments like clays, silts and sands by water and other agencies; and c) metamorphic rocks like gneisses, schists and marbles resulting from transformation of previously existing rocks due to heat and pressure.

By developing appropriate techniques and methods human communities in India made use of these various rock types right from the Stone Age. This long story of man-stone interaction can be divided into four major periods: a) Stone Age or prehistoric phase lasting till about 3000 B.C.; b) Protohistoric phase lasting till about the middle of the first millennium B.C.; c) Historical period lasting till about the 12th century A.D.; and d) Medieval period from the 12th century A.D. till the rise of colonial power. Let us examine how and for what purposes stone was used in these periods.

Prehistoric Period

It is very probable that organic materials like wood and animal bones were also used by prehistoric groups for preparing tools and weapons but unfortunately very few examples have survived the ravages of time. Stone was the most commonly used material and therefore prehistoric technology is often regarded as synonymous with stone technology. Depending upon improvements made by man both in the techniques used for working stone and in the types of artefacts fashioned out of it, prehistoric period is divided into Palaeolithic (Old Stone Age) and Mesolithic (Middle Stone Age), the former subdivided into Lower, Middle and Upper stages. During this long period of infancy man led a nomadic, hunting-gathering way of life. Based upon the evidence of absolute dates provided by scientific methods, the Lower Palaeolithic in India is dated from about two million years to two lakh years

ago; the Middle Palaeolithic from two lakh years to 40,000 years ago; the Upper Palaeolithic from 40,000 years to 10,000 years ago. The Mesolithic lasted from 10,000 years to 5000 years ago. These chronological ranges are broad ones and overlook both regional variations and cases of cultural continuity. The following aspects of stone technology during these stages are noteworthy.

On account of its fine-grained texture quartzite was used for making tools during the Lower Palaeolithic stage. Wherever it was not available, local rocks like basalts, granites, fossil wood and even limestone were made use of, thereby revealing Early Man's level of adaptability to a given set of landscape conditions. With the help of hammerstones consisting of rounded blocks of chert, quartzite or dolerite, river cobbles or fresh nodules/chunks of quartzite and other suitable rocks were flaked from one or both surfaces and fashioned into chopping tools. In many cases large flakes were struck off from these cores and, by means of soft hammers of wood or bone, these flakes were in turn transformed into other tool-types such as handaxes, cleavers, knives, awl, points, etc. In size these measured 10 to 15 cm. long. As the American anthropologist Leslie White pointed out, these artefacts served extrasomatic means of adaptation to man and were used for various life-sustaining activities such as hunting, digging up of tubers and roots, animal butchering, and cutting down of shrubs and bushes for laying one's camp.

Excavations at sites like Chirki-Nevasa (Maharashtra), Paisra (Bihar) and Bhimbetka (Madhya Pradesh) gave some interesting information about Lower Palaeolithic technology. This cultural stage is also called the Acheulian, after the French site of St. Acheul. Isampur, located in Hunsgi valley of North Karnaṭaka, is another important locality, occupying an area of three-quarters of a hectare. Excavations conducted here from 1997 to 2001 made it possible to understand various aspects of site history: its location close to a palaeochannel with a perennial waterbody and affording a good view of the surrounding uplands; on-the-spot occurrence of limestone blocks ideally suited for flaking; procurement of suitable nodules of chert, quartzite and basalt from the vicinity to serve as hammerstones; shaping of limestone blocks into cores by knocking off irregular projections; detachment of large flakes from these cores; and reshaping of these flakes into handaxes, cleavers, knives, perforators, chopping tools, etc. In the main trench (70 m^2) excavated on this site five or six chipping clusters (measuring 6 to 7 m^2 in extent) were exposed with artefacts lying in various stages of manufacture (Fig.3).

Fig. 3a. 1.2 million-year-old Lower Palaeolithic (Acheulian) cultural level exposed in excavation at Isampur in Karnataka.

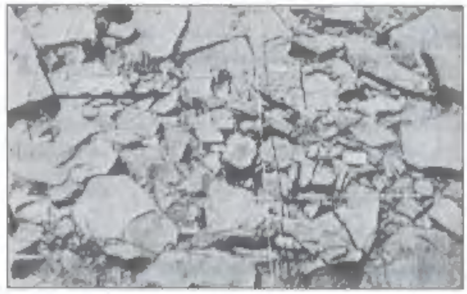

Fig. 3b. Close-up of a chipping cluster.

At these working clusters two or three persons were actually sitting and carrying out tool-manufacturing activities.

Stone technology was far from static in the Lower Palaeolithic and, on the contrary, showed progressive developments both in the methods of working and in tool-types. In the case of sites of the Hunsgi and Baichbal valleys, three stages of development were identified. In the early and middle stages the tools were large in size with thick and sinuous edges (Fig.4).

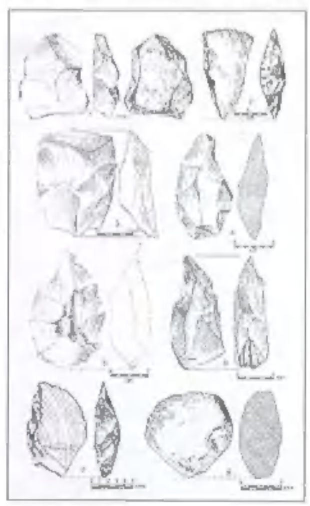

Fig. 4. Early Acheulian artefacts from Isampur in Hunsgi valley, Karnataka (core, cleavers, handaxes, perforator, knife and hammerstone).

In the final stage handaxes and cleavers became thinner and smaller and were obtained by fine quality chipping (Fig.5). It is probable that these artefacts were no longer held in hand but were hafted to wooden shafts to form spear- and lance-heads or axe-like cutting tools.

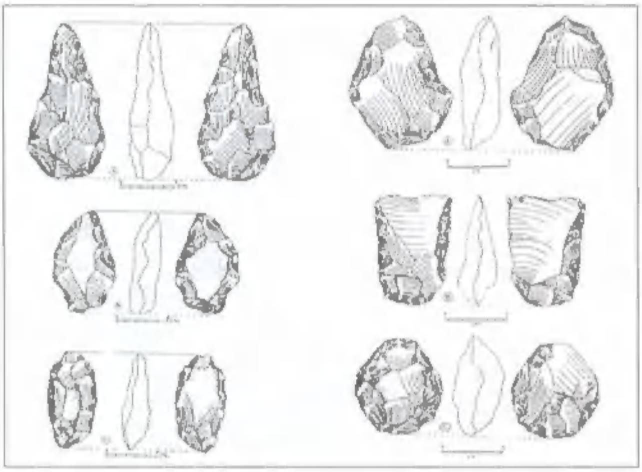

Fig. 5. Evolved Acheulian artefacts from Mudnur in Baichbal Valley, Karnataka (thin cleaver, handaxe, leaf-shaped points and discoids).

Employing the principles of Genetic Epistemology developed by the famous Swiss psychologist Jean Piaget, Thomas Wynn and other American anthropologists studied the Lower Palaeolithic tools for making inferences about the level of cognitive abilities possessed by Stone Age groups. They concluded that the preparation of handaxes and other tools already involved developed mental operations like reversibility and whole-part relations, which are characteristic of modern man.

The succeeding Middle Palaeolithic stage witnessed important technological developments. First, although quartzite use continued in some areas, siliceous materials like chert, jasper and agate, obtained as pebbles or nodules, were used now in many areas. These were flaked with stone or soft (bone or wooden) hammers and the resultant flakes were retouched along edges and transformed into smaller (6 to 8 cm across) tools such as scrapers bearing edges of different shapes, points, borers and knives. Excavations at Samnapur in Madhya Pradesh exposed an extensive tool-making and occupation site (Fig.6). Free availability of siliceous materials on the landscape and reduced size of artefacts, permitting easy transportation, enabled the Middle Palaeolithic groups to penetrate into new areas.

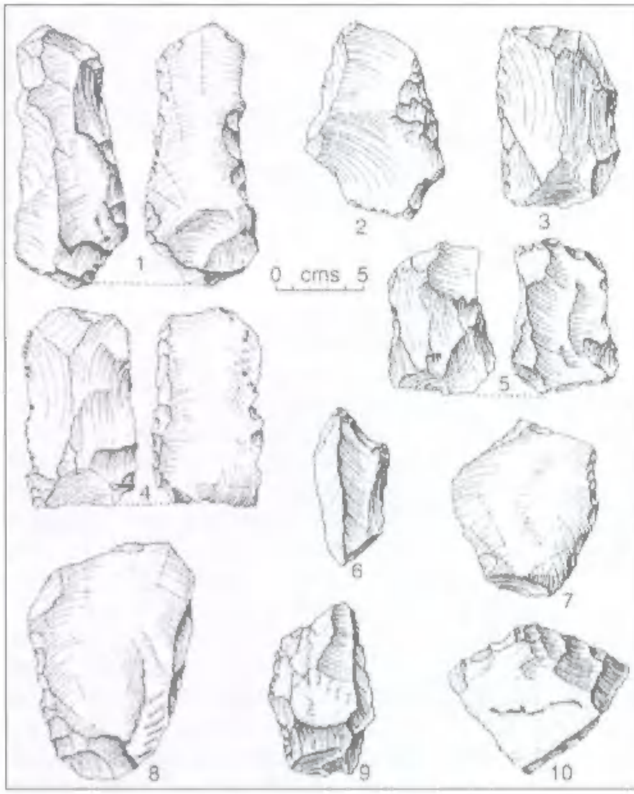

Fig. 6. Middle Palaeolithic artefacts (scrapers, knives, etc.) from Samnapur excavation, Madhya Pradesh.

Further technological refinements took place in the Upper Palaeolithic stage. Long, parallel-sided blades (8 to 10 cm long) were detached from cylindrical cores of siliceous materials; and these were retouched into blunted blades, penknives, points, scrapers and burins (Fig.7).

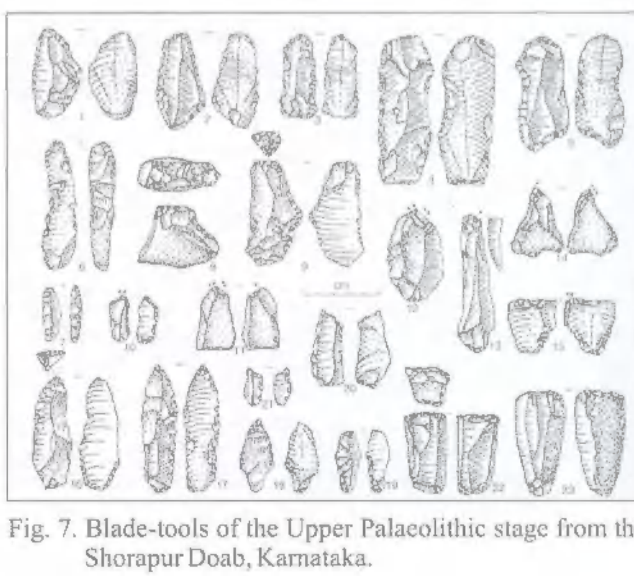

Fig. 7. Blade-tools of the Upper Palaeolithic stage from the Shorapur Doab, Karnataka.

Excavations at Patne in Maharashtra exposed evidence of three developmental stages in Upper Palaeolithic technology. Kurnool caves gave evidence of bone tools. Blade-tool tradition continued into the Mesolithic but became much smaller or microlithic (2 to 3 cm long) (Fig.8).

Fig. 8. Microlithic artefacts (blades, crescents, triangles, etc.) from Patne excavation, Maharashtra.

Recent excavations in Jwalapuram caves of Kurnool region revealed a continuous sequence of microlithic tradition dated between 35,000 and 10,000 years ago. The microlithic artefacts were used as insets for preparing composite tools like harpoons, arrowheads, saw-edged tools and knives (Fig.9). These technological developments facilitated hunting of fast-moving game. Mesolithic groups occupied all ecological zones in the country.

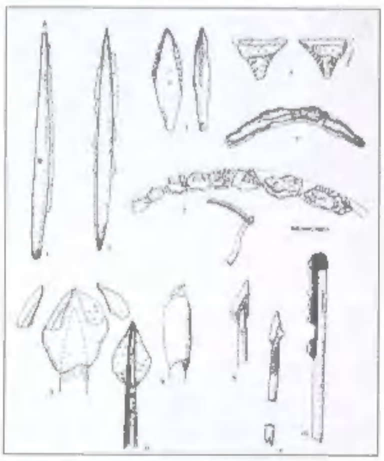

Fig. 9. Composite tools (arrowheads, sickles, knives) with hafted microliths from various sites in Europe, West Asia and Australia.

But the above observations should not be taken to mean that prehistoric groups used stone only for making tools and weapons. From the late Palaeolithic/Mesolithic stage onwards, flat rock surfaces in caves and on hillsides were used for executing bruisings and paintings of animals and other figures (Fig.10). The Bhimbetka complex of caves near Bhopal is a well-known site from this point of view.

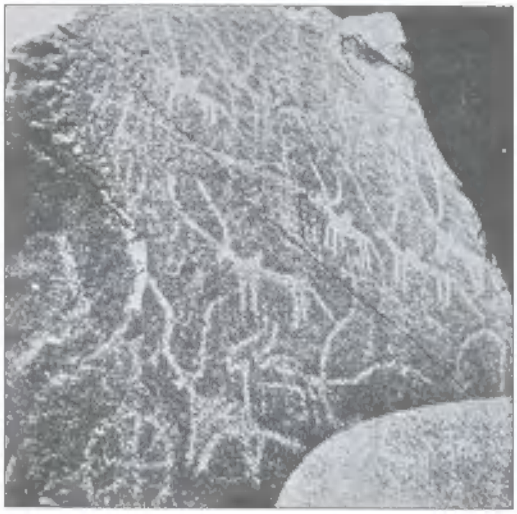

Fig. 10. Bruisings of bulls on standing granite rock from the Neolithic site of Maski, Karnataka.

There are also clues that the Stone Age groups already started attributing divine qualities to queer-looking or attractive stone blocks found in nature. For example, the late Palaeolithic site of Baghor I on the Son river in Madhya Pradesh revealed in excavation a stone rubble platform on which a triangular-shaped stone block (15 cm high) with bright-coloured natural laminations was installed and probably worshipped as manifestation of *Mai* or Mother Goddess, exactly like what the Kols and other local groups still do (Fig.11).

Fig. 11a. Stone rubble platform (shrine?) exposed in excavation at the late Palaeolithic site of Baghor I in Madhya Pradesh.

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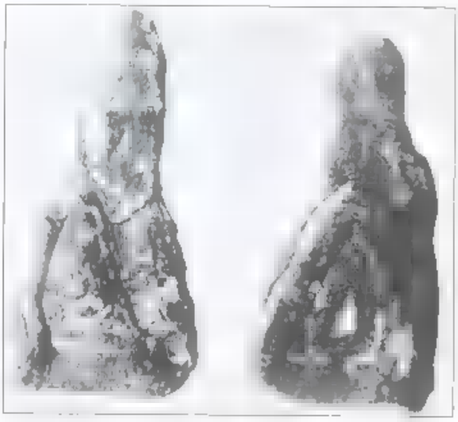

Fig. 11b. Obverse and reverse position of a triangular shaped sandstone block from Baghor I bearing coloured laminations and probably worshipped as a manifestation of mother goddess.

Protohistoric Period

Blade tools of siliceous materials continued into the Neolithic or New Stone Age which winessed the emergence of first agropastoral communities. This stage also saw the introduction of a new stone tool tradition consisting of ground and polished tools. While artefact types like querns, rubberstones and hammerstones were used for processing plant foods such as grains and seeds, sharp-edged tools like axes, adzes, chisels and hoe-blades were employed for wood-working including house-building, vegetation clearance and primitive agriculture (Fig.12).

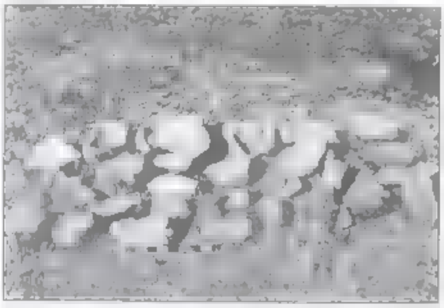

Fig. 12a. Neolithic stone querns and rubber stones.

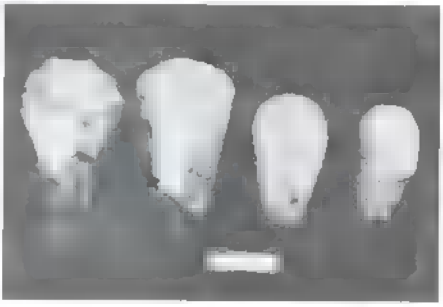

Fig. 12b. Polished axes from Budihal, North Karnataka.

The introduction of iron technology in the early part of the first millennium B.C. brought about a revolutionary change in man's use of stone. Aside from its use for making tools and implements, stone was now also used for raising imposing stone memorials (hence called megaliths) for the dead. Iron implements such as axes, adzes, chisels, points and earth-digging implements facilitated dislodgement of large blocks or slabs (up to three metres in length) from hillsides and their transportation for several kilometers across the landscape. These blocks were used for constructing four or five major tomb types called stone circles, stone cists, menhirs, dolmens and stone alignments. Sites housing dozens of such tombs or memorials for the dead are a common sight in South India and Vidarbha (Fig.13 and 14). Iron technology also facilitated creation of small irrigation tanks in basin-like natural depressions formed in hilly areas.

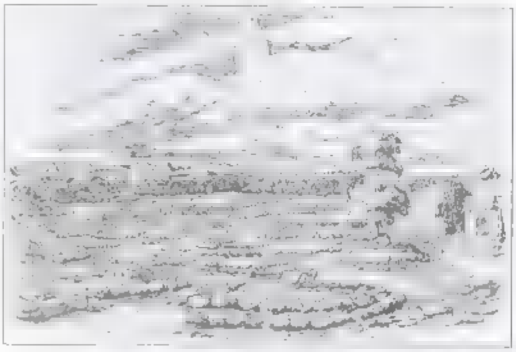

Fig. 13. Stone circle graves of the Iron Age from Jewargi, North Karnataka.

Fig. 14. Dolmens or box-like memorial tombs of the Iron Age from Rajankolur, North Karnataka.

Historical Period

In the historical period the use of stone for mega-purposes proliferated further and assumed many forms. Besides improvements in iron technology, religious developments like the rise of Jainism and Buddhism and new political processes like Magadhan ascendancy and state formation led to exploitation of stone on a large scale and for different purposes.

First, stone was quarried from hillsides and freely used for raising imposing religious monuments like temples (e.g. Khajuraho, Konark and Halebid) and stupas (e.g. Amaravati, Sanchi and Bharhut) (Fig.15 and 16). This obviously involved transportation of large blocks over long distances from hillside quarries. For example, the limestone slabs bearing figures in bas-relief used for encasing the Amaravati stupa were obtained from Macherla quarry lying some 70 to 80 km further upstream on the Krishna river.

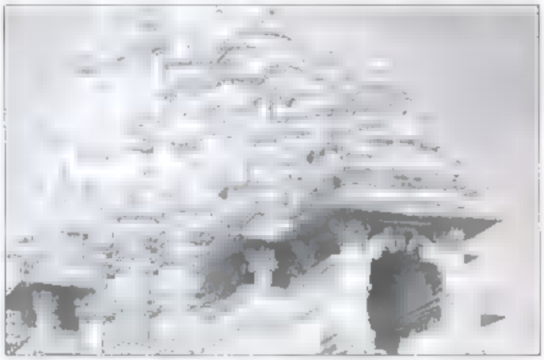

Fig.15. Temple of Chandela period at Khajuraho in Madhya Pradesh.

Fig.16. Stupa at Sanchi in Madhya Pradesh.

A second category of religious monuments consists of excavations made into hills e.g. Hathigumpha caves in Orissa, Elephanta, Karle and Ajanata caves in Maharashtra and caves for the Ajivaka sect dug in the Barbara hills of Bihar. Monuments sculpted out of hillsides represent another imposing category. You have, for example, the famous Kailasa temple at Ellora and the rock-cut rathas of the Pallava period at Mahabalipuram (Fig.17 and 18). The creation of these structures implies that the artisans carefully surveyed the hillsides and satisfied themselves about the hard and flawless character of rockbeds before the commencement of actual excavation.

Fig. 17. Kailas temple at Ellora in Maharashtra.

Fig. 18. Sketch of five rock-cut rathas at Mahabalipuram (1816).

A third use to which stone was put in the historical period concerns the preparation of sculptures and images. Regular quarries came up for this purpose near hillsides. For example, Vidula Jayaswal's investigations have shown how the famous Chunar quarry in Bihar was used during the Mauryan and Gupta periods. Various rocks like sandstone, basalt, granite and limestone were used for preparing statues and images. Consider, for example, the famous Sarnath sandstone pillar with lion capital bearing inimitable polish or the majestic Gomateswara statue at Sravana Belgola in Karnataka (Fig.19). No less imposing are the low-relief figures forming part of the Descent of Ganga or Arjuna's penance panel on the rock face at Mahabalipuram or sculpted friezes on temple walls (Fig.20), as for instance at Khajuraho or Belur and Halebid or the thousand and odd sculpted divinities of the Hindu pantheon decorating the sides of the 11th century step-well at Patan in Gujarat.

Fig. 19. Gomateswara statue at Sravana Belgola in Karnataka (Colin Mackenzie collection of drawings. 1806).

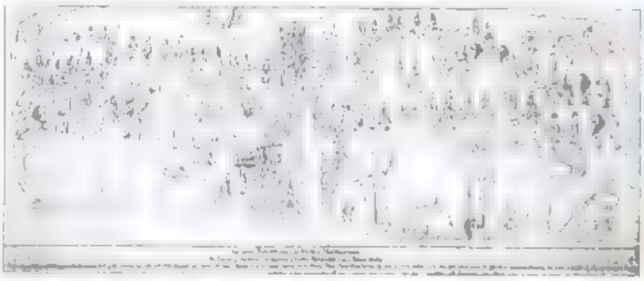

Fig. 20. Arjuna's penance or Descent of Ganga panel sculpted on rock cliff at Mahabalipuram (Colin Mackenzie's drawing, 1808).

Let us also remember that in the historical period stone was used for engraving inscriptions recording the achievements of rulers (e.g. the Hathigumpha inscription of the Kalinga ruler Kharavela or the Aihole inscription of Chalukya ruler Pulakeshin or the Nasik inscription recording the achievements of the Satavahana ruler Gautamiputra Satakarni or the ethico-religious precepts of the Dhamma policy of Asoka (Fig.21).

Fig. 21. Edict of Asoka in Brahmi script on the Girnar Gujarat.

Medieval Period

These various uses of stone for religious and mundane purposes continued in the medieval period. Now came to the fore its use for military purposes. Consider, for instance, the way the Vijayanagara rulers subdued the rugged granite hills of the Tungabhadra Valley and built one of the richest and beautiful towns of the medieval period. Equally, look at how the Maratha chiefs overpowered the lofty Sahyadris and raised dozens of forts on their summits (Fig.22). Likewise, in the north the Rajput rulers developed a series of hill-forts. This is of course not to say that the use of stone for expressing human emotions like love and respect for the dead was given up. Then we would not be having amidst us monuments like the Humayun's tomb in Delhi or Taj Mahal in Agra or Golgumbaz in Bijapur.

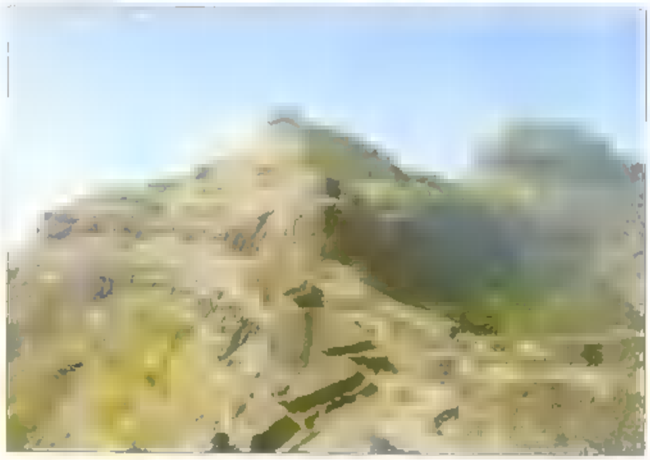

Fig. 22. Fort at Rajgadh in Maharashtra (first capital of Chatrapati Shivaji).

Conclusion

Notwithstanding all developments in modern technology and increasing use of artificial materials, stone continues to be used extensively in modern India – be it for building construction, be it for making *pathas*

Fig. 23a. Workshop for making flat grinding stones (*pathas*) and other domestic implements, Pune City.

Fig. 23b. Finished implements.

and grinding stones which are found even in the urban households (Fig.23), be it for creating images of the Nataraja and other divinities or be it for creating works of art like the expensive and large-sized marble figures of tigers and elephants. Indeed, stone has surpassed time.

In this review we have tried to capture in a non-technical language the two-million-year-long story of man's use of stone for various purposes. We have considered how beginning with his simple flaking technology to create crude tools that served as his extracorporeal limbs for obtaining wild plant and animal foods, man enhanced his understanding of stone's properties and how he used it not only to subserve his lower as well as higher level material needs but also to give concrete expression to his emotional urges like aesthetic appreciation, love and respect to departed ones and religious feelings. The essence of our story is that stone has not only responded to the various callings of human urges but has preserved the consequences of actions emanating from these urges in a solid and interpretable manner. Although mute by its geological nature, in interaction with man stone began to take shapes and speak!

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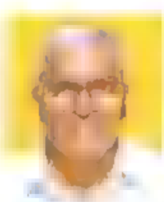

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Glimpses of cosmic menagerie through S. Chandrasekhar's eyes

Patrick Das Gupta** and **N. Rathnasree,

Abstract

This article provides an exposition to Subrahmanyan Chandrasekhar's seminal contributions to wide ranging topics in astrophysics - from white dwarf mass limit to blackholes and gravitational waves, in the light of observational astronomy. Most of the results obtained by Chandrasekhar led to far reaching consequences in astrophysics, many of them experimentally validated.

Chandrasekhar Limit

Subrahmanyan Chandrasekhar's astrophysical journey had begun in the year 1928 with the publication of his first paper when he was barely 18 years old[1]. His impactful voyage across oceans began on July 31, 1930, from Gateway of India at Bombay. The Italian liner, the Lloyd Triestino, on its way through the stormy seas onward to Venice, had as its passenger, 19 year old Chandra on his way to England, with a government scholarship, for higher studies. During that momentous voyage, he (who had chewed and digested Fowler's work on white dwarfs[2]) was struggling with the mathematical equations concerning very dense stars, known as white dwarfs, whose beauty and elegance moved and motivated young Chandra to unravel the underlying physical consequences.

What are white dwarfs? Before answering this question, let us have a quick glance at the stellar evolution theory. Nuclear fusion of hydrogen to helium is the main fuel store of a main sequence star like Sun that provides necessary thermal energy to stall the gravitational contraction, and helps the star in attaining a quasi-hydrostatic equilibrium. As the star advances in its life cycle, a further sequence of nuclear fusion reactions play themselves out in its core - helium burning to carbon and oxygen, carbon burning to sodium and magnesium and so on, if the star is massive enough, till the eventual formation of iron rich core. Iron nucleus being the most stable one, further nuclear burning cease to take place. As the star cools, it collapses under its own weight, till the electron density becomes so high that electron degeneracy pressure prevents subsequent contraction.

What is electron degeneracy pressure? In quantum mechanics, Pauli exclusion principle (PEP) states that no two identical fermions can have the same state. Electrons, being spin half particles, are fermions. According to PEP, in a gravitationally bound system like the iron-rich core of an evolved star, all the electrons cannot occupy the lowest energy level (unlike the bosons in Bose-Einstein condensates). Therefore, the energy levels have to be filled up with two electrons per orbital (one spin up and other spin down, so that PEP is maintained). Hence, more the density of electrons, higher is the energy level that gets to be occupied.

Gravitational contraction of such a dense core leads to an increase in electron density, thereby facing a resistance since the contraction implies putting electrons at higher energy levels. So, in such a degenerate system, gravitational collapse instead of lowering the energy of the star tends to increase it. The resulting pressure against contraction, arising out of PEP in such electron rich dense matter is called electron degeneracy pressure (EDP). A white dwarf is a star that is in hydrostatic equilibrium not because of thermal pressure but due to the EDP that counteracts gravitational contraction. Assuming that electrons could be treated non-relativistically, Fowler had shown that the EDP in the core of a white dwarf is proportional to $\rho^{5/3}$, where ρ is the density of the core[3].

On board Lloyd Triestino, while studying the white dwarf problem, Chandra had realized that at such incredible densities inside a white dwarf, electrons would be occupying very high energy levels, whizzing around with velocities close to that of light. He proceeded to incorporate special relativity in the analysis, and found that the EDP is now proportional to $\rho^{4/3}$.

Performing an accurate study of the relativistic problem of a dense star ruled by a polytropic equation of state, in which gravity was countered by the EDP, he arrived at the celebrated Chandrasekhar mass limit[1],

$$M_{Ch} = \frac{0.2}{(m_p \mu_e)^2} \left(\frac{\hbar c}{G}\right)^{3/2}$$

where $\hbar$, G, c, m_p and μ_e are the reduced Plank's constant, Newton's gravitational constant, speed of light, mass of a proton and mean molecular weight per electron, respectively. It is remarkable that a significant result concerning stars should be expressible in terms

of fundamental quantities (except for μ_e). In white dwarfs, the value of μ_e is such that the above expression leads to

$$M_{Ch} \approx 1.4\ M_{\odot}, \text{ where } M_{\odot} = 2 \times 10^{30}\ \text{kg},$$

is the sun's mass.

Chandra was unaware initially that Anderson in 1929 and Stoner in 1930 had independently applied special relativity to obtain mass limits for a degenerate, dense star of uniform density without taking into account the condition of hydrostatic equilibrium[4,5,7]. Fowler pointed this out to him when Chandra reached Cambridge, and he added these references to his papers on relativistic degeneracy in white dwarf stars[6].

The Chandrasekhar mass limit implies that no white dwarf with mass greater than this limit can hold out against gravitational collapse. So far, all the white dwarfs discovered (like Sirius B, the companion star to Sirius) in the cosmos, have mass less than M_{Ch}. For masses beyond this limit, Eddington had found the idea of a star shrinking to a point absurd. After about three decades, Penrose and Hawking, making use of Raychaudhuri equation proved the celebrated singularity theorems according to which collapse of normal matter indeed lead to point singularities, namely, the blackholes[8-10]. We shall discuss towards the end, Chandra's contribution to the mathematical theory of blackholes.

Dynamical Friction

Chandra played a significant role in the research area of stellar dynamics from 1939 to 1944 that culminated in the publication of his celebrated papers on dynamical friction[11,12].

Cosmos is filled with gravitationally bound systems of massive objects like globular clusters, galaxies, clusters of galaxies, etc. Objects that make up these bound systems, apart from moving in gravitational potential wells, also suffer two-body gravitational encounters, resulting in exchange of energy and momentum. It was Chandra who showed for the first time that a massive body in motion, surrounded by a swarm of other less massive objects, suffers deceleration that is proportional to its mass[11].

Dynamical friction arises out of cumulative gravitational encounters that the massive body suffers due to the presence of other objects in the background. The origin of dynamical friction can be intuitively understood by going to the reference frame in which the body is at rest. In this frame, the swarm of background objects while moving past the massive body get gravitationally focused behind the body, forming a wake of higher mass density. Now, switching back to the frame in which the massive body is moving, we find that the mass density of the wake behind is greater than the density ahead. Consequently, because of a greater gravitational pull from behind, the massive body experiences a gravitational drag force whose magnitude is proportional to the square of its mass and inversely proportional to the square of its speed[13-15].

Observational consequences of dynamical friction include sinking of globular clusters towards the central regions of galaxies and galactic cannibalism in which the orbit of a satellite galaxy decays, leading eventually to its merger with the bigger galaxy[14].

Negative Hydrogen Ion

Around the same time, Chandra was also involved with the quantum mechanics of negative hydrogen ion. Can a proton capture two electrons to form a charged bound state? How is it relevant to astrophysics? The first issue had, once for all, been settled by Bethe in a 1929 paper, that according to quantum theory, H^- ion can indeed form[16]. Coming to the second question, it has been found over the years that H^- is a weakly bound system with a binding energy of

$$\approx 0.75\ \text{eV}.$$

As it takes only about 0.75 eV to knock off the extra electron from H^-, its life-time under terrestrial conditions is small but in thin and tenuous plasma where the collision frequency is low, one expects negative hydrogen ions to survive for longer duration.

So, early on, Wildt had foreseen that because of copious presence of hydrogen atoms and electrons in the upper atmosphere of Sun, H^- would form and photo-detachment of H^- would contribute majorly to solar opacity[17-19].

At this juncture, Chandra and his collaborators played an important role in calculating H^- photo-absorption matrix element, so crucial for opacity estimation[20-26].

In 1943, Chandrasekhar and Krogdahl drew attention to the fact that dominant contribution to this matrix element came from the wavefunction at large distances (several times Bohr radius), and therefore an accurate knowledge of electronic wavefunction of H^- was required[20].

The negative hydrogen ion has only the ground state as a bound state with the possibility of singly excited states ruled out. As a result, photons with energy above 0.75 eV, executing random walks out of Sun due to multiple scatterings, would be absorbed by H^- ions after detaching their extra electrons to the continuum. This is the dominant cause for solar opacity in the infra-red to visible range.

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Chandra and his collaborators made seminal contributions towards calculating the continuous absorption coefficient κ_λ of H as a function of the photon wavelength λ, incorporating dipole-length and dipole-velocity formulae, that provided a solid theoretical foundation for the characteristic κ_λ- λ plot which exhibits a rise in the range 4000 to 9000 angstroms, then dropping to a minimum at 16000 angstroms, with a subsequent rise[27].

Interestingly, the negatively charged hydrogen ion has been in great demand for cyclotrons and particle accelerators[28]. Fascination for H arises out of the possibility of using it for heating neutral beams in Tokamaks (like in ITER), because of the relative ease in detaching its extra electron when these ions are present in gas cells[29].

Magnetohydrodynamics and Chandrasekhar number

Almost all cosmic entities are threaded with magnetic fields, be it planets like Earth, Jupiter, etc., sunspots, stars, spiral arms of Milky Way, galaxies and so on. Magnetic field in conducting medium like metal or plasma decays due to Ohmic dissipation. So, how does terrestrial magnetic field generated by the electric currents flowing in the molten, conducting and rotating earth's core prevent itself from Ohmic decay?

Dynamo theories involving magnetohydrodynamics strive to provide explanations to this conundrum. In this paradigm, differential rotation and convection in conducting fluid are invoked to generate steady magnetic fields. Cowling had proved that a completely axisymmetric geometry for magnetohydrodynamic flow will always result in a decaying magnetic field[30].

Two decades later, Backus and Chandrasekhar generalized Cowling's theorem[31]. In this context, Chandra tackled the possibility of increasing the decay duration so that an axisymmetric dynamo is still relevant for geomagnetism[32]. But soon Backus showed that the increase was not large enough to be of geophysical interest[33].

Chandra also studied several fluid dynamical stability problems employing variational methods that had far reaching consequences[34, 35].

A stellar binary system consisting of an expanding star, spewing out gaseous matter, and a massive compact object (MCO) like a neutron star or a blackhole (BH) going around the centre of mass, is often invoked to explain astronomical sources emitting high energy photons. In such a binary system, gas from the bloated star cannot radially fall on the MCO because it possesses angular momentum. Instead, it spirals inwards and forms an accretion disc around the MCO, with each tiny gaseous element of the disc moving in a circular Keplerian orbit[36]. Fluid elements of the disc rotate differentially so that farther the element from the MCO, lower is its circular speed. Differential rotation leads to viscous rubbing of neighbouring fluid elements, causing the accretion disc to become so hot that it emits copious electromagnetic radiation from visible spectrum to UV and X-rays.

In fact, there are strong observational evidences that the rapidly time varying, intense X-ray sources like Cygnus X-1 are accreting blackholes. Essentially, the gravitational potential energy of the gas falling in, due to MCO's gravity, gets converted into radiative energy. But, for the conversion efficiency to be large, the accretion disc is required to have a high viscosity. The physics of the mechanism responsible for large viscosities in the disc is an active area of research.

Interestingly, as shown by Balbus and Hawley in 1991, the Chandrasekhar instability might be the key to the origin of accretion disc viscosity[37]. Chandra had pointed out that a differentially rotating, conducting and magnetized incompressible fluid in a cylindrical configuration, is unstable with respect to oscillating axisymmetric perturbations[34].

While investigating Rayleigh-Benard convection in conducting and viscous fluids threaded with magnetic field, Chandra studied the onset of convection and its dependence on a dimensionless number Q, representing the square of the ratio of magnetic force to viscous force[38]. Today, this number Q is referred to as Chandrasekhar number (or, also as the square of Hartmann number).

Chandra made several other contributions in the field of plasma physics and magnetohydrodynamics that had far reaching consequences[*].

Rotating self-gravitating fluids and Chandrasekhar-Friedman-Schutz instability

In the late 1960s, Chandra turned his attention to incompressible fluids in gravitational equilibrium[39]. While studying self-gravitating and rotating fluid configurations, Chandra showed that a uniformly dense and uniformly rotating incompressible spheroid is unstable because of non-radial perturbations emitting gravitational radiation[40]. Later, Friedman and Schutz in 1978 demonstrated the existence of this gravitational wave driven instability in the general case of rotating and self-gravitating stars made of perfect fluid[41].

A physically intuitive way to understand this Chandrasekhar-Friedman-Schutz (CFS) instability is to look at a perturbation mode in a rotating star that is retrograde, i.e. moving in the backward sense relative to the fluid element going around. According to general relativity, the space-time geometry around a rotating body is such that inertial frames are dragged along the direction of rotation (This has been recently verified by the Gravity Probe B satellite-borne experiment[42]). This frame dragging, therefore, would make the retrograde mode appear prograde to an inertial observer far away from the star. Gravitational waves emitted by this mode will carry positive angular momentum (i.e. having the same sense as the angular momentum of the fluid element) as measured in the distant inertial frame. Since, the total angular momentum is conserved, gravitational radiation carrying away positive angular momentum from the mode, makes the retrograde mode go around more rapidly in the opposite direction, leading to an instability.

Andersson in 1998 showed that a class of toroidal perturbations (the so called r-modes) in a rotating star are generically unstable because of the gravitational wave driven CFS instability[43]. Close on heels, it was demonstrated that the r-mode instability would put brakes on the rotation of a newly born and rapidly spinning neutron star[44-45]. Consequently, as the neutron star spins down, a substantial amount of its rotational energy is radiated away as gravitational waves, making it a likely candidate for future detection by the laser interferometric gravitational wave detectors, namely, the LIGOs[46]. Thanks to LIGOs, the CFS instability, discovered by Chandra for the first time, may soon be put to experimental tests.

Blackholes

In his book on blackholes (BHs), Chandra called the astrophysical BHs the most perfect macroscopic objects[47]. Things macroscopic - like chairs, books, computers, etc. around us, require an astronomically large number of characteristics each for their description. For instance, just to specify a sugar cube would need not only its mass, density, temperature, but also amount and nature of trace compounds present, the stacking of sugar molecules, porosity, surface granularities, etc. On the other hand, a BH is characterized by just three real parameters - its mass, charge and angular momentum.

But do BHs exist? As classical BHs by themselves do not emit any radiation (Hawking radiation, which is of quantum mechanical origin, from astrophysical BHs, is too miniscule in amount to be of any observational significance[48]), how does one find them? In conventional astronomy, their detection relies on the presence of gas or stars in their vicinity and the ensuing stellar or dissipative gas dynamics around an accreting MCO.

As discussed earlier, if the MCO has an accretion disc around it like in galactic X-ray sources, quasars, blazars or radio-galaxies, the swirling and inward spiralling gas gets heated up, emitting radio, optical, UV and X-ray photons, often accompanied by large scale jets[49]. From causality arguments applied to time variability (on the scale of few hours in blazars) and from spectral nature (e.g. presence of the big blue bump in quasar spectrum) of the radiation emanating from such an accretion disc, one can infer the presence of a BH. The models that provide the best explanations for the observational data about quasars, blazars, radio-galaxies, etc. involve an accreting supermassive blackhole, having a mass in excess of $10^6 M_\odot$ [49].

Similarly, by monitoring stellar dynamics around the central region of Milky Way for decades, one infers that the Galactic nucleus contains a heavy and compact object, most likely to be a supermassive BH with a mass of about $4 \times 10^6 M_\odot$, within a radius of 10^{15} cm from the Galactic Centre[50]. It is interesting to note that the Chandra X-ray observatory (launched on July 23, 1999, and named after S. Candrasekhar) revealed the presence of a X-ray source as well as hot gas with high pressure and strong magnetic field in the vicinity of the Galactic Centre.

However, these are indirect detections, implying strictly speaking the presence of a very compact, massive central object. Inference of an astrophysical BH, although very likely, relies on theoretical interpretation. BHs are characterized by a fictitious spherical surface called the event horizon centred around the point singularity created by the collapse of matter. Nothing can escape from regions enclosed within the event horizon. What happens when a BH is perturbed by incident gravitational waves or electromagnetic radiation or Dirac waves describing electrons or neutrinos? Does a perturbed BH have a signature emission like a 'ringing', analogous to the case of a struck bell? To answer such questions, Chandra devoted himself to studying BH perturbations from 1970s onwards[47,53-57].

When a BH is perturbed, the curved space-time geometry around the BH will be subjected to metric fluctuations. For sufficiently small perturbations, a linear analysis of the metric fluctuations can be carried out in terms of normal modes except that dissipation due to both emission of gravitational waves as well as energy loss caused by BH absorption makes the mode frequencies complex, with the decay reflected in the imaginary parts. In the case of a perturbed BH, such quasi-normal modes (QNMs) correspond to a characteristic ringing that eventually decays due to

QNMs were discovered by Vishveshwara[51] and Press[52] while studying gravitational wave perturbations of BHs. Chandra and Detweiler suggested for the first time numerical methods for calculating the QNM frequencies[53]. Such investigations throw light on methods for direct detection of BHs. For example, matter falling into a Schwarzschild BH would lead to excitation of QNMs, resulting in emission of gravitational waves with a characteristic frequency that is inversely proportional to the BH mass. A supermassive BH with mass $10^{6} M_{\odot}$ would ring with a frequency of about 10^{-2} Hz. Because of seismic noise, LIGOs cannot detect gravitational waves having such low frequencies. Only a space-based gravitational wave detector like LISA (Laser Interferometer Space Antenna) can pick up such low frequency signals from supermassive BHs.

In 1983, Chandra was awarded the Nobel prize in Physics. The lesson we learn from his way of researching astrophysical topics is that one can make accurate and far reaching predictions concerning cosmic entities, by using standard laws of physics applicable to these problems, and then subjecting them to rigorous mathematical analysis. Looking at Chandra's achievements, one is overwhelmed by the diversity of his research contributions, most of which have experimental validation.

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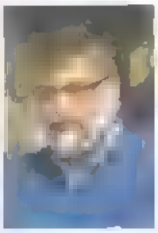

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Science Broadcasting: Experiences, explorations and experiments

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Abstract

This is a personal journey with events that evoke emotions, provoke passions, and pose problems. In real life, aims, goals and objectives meet chance and necessity at different points of time and happy coincidences provide opportunities for one to serendipitously stumble upon solutions. Summarising the last three decades of this journey leads to strategies for improving science coverage in Indian television.

In the beginning

1982. As a young man struggling to survive as a freelance science journalist, I faced an interesting proposition: "You have so many interesting science ideas. Why don't you write a script for me?" I had no problems collaborating with the freelance TV producer, a friend.

Writing in newspapers and magazines, however, had not prepared me to write scripts for television. But the revisions that they underwent in discussions with the producer, and seeing the script get executed as a programme, did the trick. So the second script for another producer was faster. I could even make myself useful during production. And then, writing the narration script for yet another producer completed my course on script and narration writing.

In the process, I realised that, though these producers were all involved with science programmes, none of them had a background in science. Studying foreign languages, political science, or international relations, they had wandered into producing science because they were interested in film making. (TV used black-and-white 16-mm film those days, and it was a stepping stone to the film Industry.)

So I went to Old Man Charlie, the Chief Editor of Television News Features, with yet another script and requested him to let me direct it. Having seen shooting, editing, animation, etc., at close quarters for three programmes, I was ready. Charlie would not stand in the way of scripts. But he would sit with the producers after shooting and editing, and look at the narration script. He would read each sentence and even repeat some words, asking: "will this be understood by the rickshaw puller?" He did this with each narration script for all the five programmes that I produced there later. What better training could one have?

Changing technologies, evolving skills

Suddenly the technology changed: video became the medium for TV production. And I wandered into educational television. A degree in physics and a Masters in life sciences were not qualifications that people look for in a TV producer. But for making science programmes they had advantages. Five black-and-white films were good enough as certificates to enter the world of educational television. It did not take much time for me to be known as a "science" producer amongst those making UGC programmes. (A label which I had to shake off quickly by making a few programmes in arts and humanities.)

In terms of making TV programmes, it does not really matter whether it is science or arts or sports or humanities that we are dealing with - the techniques and styles of production, however, make a large difference to whether the programme is worth watching. Ultimately, it is the passion of the producer and his or her insights about the subject of the programme that makes a production excellent. If we are not moved by an idea, we cannot make a programme that moves others.

The shift from science to education in general gave me the scope to experiment with the medium. "Footage" in video was not as costly as in film. The cameras were easier to handle. And cameramen were not as possessive about their equipment as they were when film was used. Moreover, one was supposed to edit one's own programmes. No editor to cut and splice. No lab for processing. One could see the results immediately. The freedom to do what I liked was incentive enough to push my limits in the attempt to master the medium - and to understand education in its broadest sense.

When institutional changes clamped down on that freedom, I left quietly. Private sector television studios were opening up. And I found myself managing productions instead of producing. The excitement of shooting and editing was gone. The focus was on the message and the masses. A series of health spots with a common theme "*jara si savdhani, zindagi bhar asani*" changed the way I approached television. I did not own a television set in those days. But I could hear the refrain in the street. Seemingly endless repetitions that do not necessarily bore people.

Education calls for repetition. If I had suggested making one-minute educational programmes, would policy makers understand? Making one-minute spots called for skills different from those of making a documentary. And a one-minute news story calls for yet another set of skills. I was learning from what Marshal McLuhan called school – the world around me.

From doing to teaching

Learning from doing does not prepare one to teach. The unanticipated challenge of being the Director of a post-graduate diploma course in Science Journalism in the late 80's made me master issues related to science and journalism from a different perspective. I learnt a little formal journalism: teaching others is good incentive for learning declarative knowledge.

Theories of communication given in text books did not satisfy me. The need to base communication theory in the context of information theory on the one hand and the findings in neurosciences and sociobiology on the other, led me to attempt formulating some academic papers later. For the course, I merely gave references to the books and skipped teaching them. Conveniently.

Instead, I focussed on the practical work: the content, structure and style of the students' output. The academic inputs were related to philosophy, methodology, history, organisation of scientific research in India, sources of information, and dealing with the information explosion. These were the missing links that a science graduate does not learn, but are crucial for science journalists. General introductions to the processes in media and detailed discussions on the different elements of each media gave the students a background for adapting to the media environment.

Does all this make a science journalist? Of course not! But it was evident that all the students in the course learned to write well. 25 articles in a span of nine months, and receiving detailed feedback on each, will do that to anybody.

As I went back into TV production as Chief Producer of Medical Television, the question that kept nagging me was – What are we missing out on in journalism education in the university setting?

Back to action

Video as a medium for health communication to the public, for patient education, for training of paramedics, and for continuing medical education: it sounded as good at that time as it does now. But the time was not ripe then. Taking a salary for not doing much was not my cup of tea. So soon I was tagging along with NGOs.

A media package consisting of a video to train women to repair hand pumps, trigger tapes to initiate a discussion on the issue of water, hand pumps, women *mistries*, maintenance of hand pumps and sanitation, a handbook in comic book format so that even semi-literate women could learn the processes involved in repairing deep-well hand pumps, flipcharts and posters to be given to women who are trained – the making of the kit was a tedious process. But I learnt a lot about many development issues in a very short time – water, sanitation, health, gender, poverty, education – and their relationship with science and technology – geology of aquifers, water-cycle, integrated land and water management...

Suddenly I found myself in the area of development communication. There was a lot to be done. But there were no resources. And one had to survive. So I went back to mainstream television.

Tackling the information explosion

The technologies for TV production and transmission have changed drastically again and again, in the last three decades. Keeping up with the technology and mastering the new tools of production was never a big hurdle. But keeping up with the advances in science was becoming difficult. And then came the Internet, and easier access to scientific databases; just in time to help me when I started producing the popular science serial 'Turning Point'.

The Indian National Scientific Documentation Centre (INSDOC) had started a service called CAPS. They would provide the list of contents of the scientific journals that you selected and if you found any paper worth pursuing because of its title you could ask for the abstract and if you found the abstract interesting, you could ask for the full paper. The service was meant for scientists. But I made full use of it.

As a science journalist earlier, I used to scan *Current Contents* – a journal series that listed the contents of most journals. But then, I had to go to the university library to access *Current Contents*. The service that INSDOC offered had the option of getting the data on a floppy disc. I could sit in my office or at home and do my research.

I subscribed to 400 reasonably good journals, spanning broadly, all scientific disciplines. Scanning through just the titles of all papers from 400 journals was an

educational experience. Quite often, one was compelled to look at the abstracts. And at times the full paper. I felt like I was on the frontiers of science, without being a scientist. In fact, most scientists are not interested in topics outside their expertise. I had a ring-side view of science.

It also proved to be quite useful when talking to scientists. I was quite at ease with the terminology that they use. Of course, in the programmes one had to use simple common speech understandable to the proverbial rickshaw puller. But that does not mean that one cannot spout a few terms to signal to scientists that they could talk to me as to an equal, making interactions more fruitful, in less time.

When dealing with TV producers, some scientists like to pretend that they are the only ones working on a specific problem. Dropping references to some papers in their field during the conversation was a useful technique that I developed during those days: it stopped them from following that line, without hurting egos.

The boom and bust of dot com left behind wider Internet access. The conversion of the Internet into the commoner's medium and digital convergence, the marriage between TV and computers - had been formalised. A producer today does not have to wait for the monthly package of diskettes from INSDOC, but will perhaps go through scirus.com or Google Scholar on a day-to-day basis. The retrospective data available now, is accessible even to literate housewives.

Education: From production to programming

Dealing with the information explosion on the one hand, and the tight deadlines of a TV medium on the other, was not so easy then. As the Producer of Turning Point in the early '90's, I realised that I had to depend on others and follow the processes of a production line to meet the deadline week after week. Hence came the training of young people in TV production, allowing them to learn on-the-job, as I had learned.

It was easy to train people who had a bachelors' degree. But when I tried to get help by hiring Masters and PhD scholars, the going was not so easy. Skill building took longer. However, once they learnt the skills, they had better mileage. They could handle technical content with more accuracy and credibility.

That was a rude awakening to the process of learning in adults. But before I could reflect on the issue and hone my skills and deepen any insights in that field, I had moved on to handling the UGC broadcasts on Doordarshan.

The broadening of scope from science to education as a whole was, again, intellectually stimulating. The problem of dealing with 17 production centres distributed in different parts of the country shifted my attention away from science and into the management of broadcasting.

The task of packaging three or more programmes to fit into one-hour slots was not difficult. I had learnt that packaging was as important as production when dealing with Turning Point. But scheduling was a different game altogether. To deal with the problem of the shifts in viewers' demographic profiles with the time of the day could be tackled only by appropriate programming. Moreover, I was getting deeper into educational broadcasting, specifically to issues related to quality of production and programming as well as accuracy of the content and its relevance for the target audience. The international quality standards for management were not good enough to deal with the issues of broadcasting management. I did not know at that time, that the work on International Standards in Quality Management was being adapted for Broadcast and Print Media.

At the level of production, one had to fight the notion that education somehow has to be boring and even painful (e.g. teach a lesson, *shiksha* in Hindi which originally meant punishment) to be really effective. I gave myself a crash course on educational theories and pedagogic strategies. The inherent contradictions between the philosophies of media and of education had to be reconciled.

Moreover, the Ministry of Human Resources had transgressed into the territory of the Ministry of Broadcasting and was trying to convert it into a classroom. The work culture and ethics of the two industries – education and broadcasting – were not too congruent or even similar. Policies that did not take into account these differences had created a system that was tying itself into knots, trying to be in two boats at once.

Meanwhile, the number of satellite channels kept rising. The manufacture of satellites started adopting the production line model adopted by the automobile industry. And even UGC was given a channel. Educational television in the country faced the crisis of supply of frequencies far beyond the manpower needed to use them in any sensible way.

Running a channel which nobody watches, calls for the same effort as running a channel that everybody watches. Government sector rules do not allow converting a channel that nobody watches into something that at least 22 million would love to watch. I got out of it as fast as I could.

Leaving a job does not mean losing track of the problems and seeking solutions. I carried the questions forward. What is it that we could do to make a channel work? Given the latest technology and unlimited finances? What are the limiting factors? What can one do practically, to improve the quality of broadcasting?

Training to capacity building

As if to help me tackle these questions, my next job was to organise seminars and conferences for broadcasters in the Asia-Pacific region. Capacity building of broadcasters including sensitising and orienting them to deal with even cultural and religious issues helped me to understand broadcasting better and broadened my vision in terms of programming. Involvement with international broadcasting quality standards ISAS BC 2000 helped me understand broadcast management - human resources, technology, marketing, finance etc. - better.

In this avatar, I had to take up the training of TV and radio professionals in many different countries. The breakneck speed at which one works, does not allow time for reflections or pursuit of one's scientific quests. But many workshops with TV and radio producers taught me the difference between telling, teaching and training. Development of training tools was the only way to tackle the enormous need for adequate training in the broadcast sector in the region.

Developing training tools and materials

The skills in provoking emotions and psychosocial change through broadcast media became the focus when a series of workshops on HIV issues came my way. HIV became a pretext for me to enquire into health communication as a whole. The narrowing of perspective was useful. The ideas crystallised into a book titled: *HIV on TV -- Getting the Story and Telling it Right*, a handbook for TV producers and trainers. (Available at http://unesdoc.unesco.org/images/0018/001843/184320e.pdf).

The task of putting together a minimum standard for HIV communication through media (Available at http://www.thegmai.org/JC1657_MinimumQualityStandards eng.pdf) gave me the opportunity and time to think about development communication again. The narrow task area was able to teach me a lot about a wider area of operations.

The task of creating a science kit for broadcasters suddenly fell into my lap. As preparation for this book, I sent out a questionnaire to 26 countries in the Asia Pacific region, to understand my target audience. And I realised that some broadcasters do not have producers with science degrees. At the other end South Korea had a doctor with MD to take care of health programmes. And then came a series of workshops for radio and TV producers on Broadcasting Science -- in countries where there was virtually no science programming. This provided an opportunity for me to test out the content for the book titled *Broadcasting Science* (available at aibd.org.my/books).

While I came back a full circle to science broadcasting, but more as a trainer, the medium itself had undergone major changes. YouTube and video sharing technologies have attained a stable position in the media landscape. And the tools of production – a video camera and a computer – have become commonplace in institutions and homes. A revolution in the Marxist sense had occurred: workers could own the tools of production.

From printing press to ballpoint pen to keyboards (and mouse!), the democratisation of the printed word had taken much longer than video. But in a short span of three decades video has become a citizen's tool to communicate - even across national boundaries. The potential growth and development in this area is yet to be reached. A book *Social Video: Tips and Tricks for Citizen Journalists*, published by Publication Division, Ministry of Information Broadcasting in 2011 (not available freely on the web as the earlier references) was a step to fulfill the needs of any citizen wanting to use video.

But then, though video is used so abundantly even in the rural areas of India, it is not sufficiently understood by scientists, researchers, teachers and extension workers. It is almost as if those who have something to say are mute while village idiots are given loudspeakers.

It appears that scientists need to be trained if a channel - as mooted by the Knowledge Commission and as actively "considered" by CSIR and other organisations - has to become viable and sustainable.

A Science Channel?

There are more than 400 TV channels in India. One more of course, may not hurt. So why not?

While there are channels fully focussed on politics, business, religion, music, sports or fashion, (why, even one that is focussed only on golf) a channel focussed on science would be a welcome addition. (We can fight about what language, etc., later).

While growth is measurable in terms of numbers, development defies measurement but is manifest in terms of evolution of diversity and specialisations that can be differentiated. A science channel would not be just another channel, but an indication of broadcast development.

But then, a science channel cannot just take off and sustain itself easily. At least, this is what we must surmise from the earlier failed attempts in India (by DECU), and abroad (a channel called Einstein). The restraining force is simple enough to identify: manpower. The intellectual capacity needed to deal with science and technology issues on radio or television is higher than what is needed to make a reality show or to report the changing numbers of Sensex.

The explosion of FM stations – commercial, community and campus radio – have put further strains on the supply side of manpower for the broadcast industry. The university sector in India may not be able to match their output to the needs of the industry. So the broadcast industry will grow by absorbing untrained people and let them learn on the job – as usual. But this growth alone does not necessarily lead to the development of the broadcast sector.

Challenges ahead

The next generation of science broadcasters should theoretically come from the departments of science journalism or mass communication or electronic journalism. But just as a Master's degree in mathematics does not make one a mathematician, getting a degree even in science broadcasting will not turn one into a science communicator adept at handling radio or TV media.

Broadcast media which works 24/7 expects high productivity from its human resource. A Master's degree does not train people to handle the pressure. So quite a few turn to teaching as a profession. You could take five years to write a thesis while broadcast media expects at least one programme per month, if not one or more stories every week (depending on the genre of programming).

This disconnect between education and the media industries came out clearly during the expert group discussions organised by UNESCO a few years ago, to formulate journalism curricula. The industry leaders were clear that they would prefer people who can handle content. Thus an MA in Economics is preferable for a media channel that specialises in economics and business. Once a person gets inside the industry, learning the technology and techniques of the medium is not difficult. But for a person with MA in Mass Communication it is less easy to deal with the complexities of topics in economics and business or science.

So would injection of some scientific topics in science journalism courses help in developing the adequate human resource needed for science broadcasting? Or should we inject some topics in journalism into science courses?

One could, of course, try both strategies. But it would take quite some time to get the right kind of manpower required to create content with science coverage of more than 10% in media. (At present, it is estimated to be about 2 to 4 percent - lesser in broadcast media.)

And what indeed are the characteristics of people that the industry would need?

1. Wide range of scientific interests and curiosity beyond the narrow disciplines defined by the university system.
2. Enthusiastic and excitable about scientific ideas.
3. Ability to comprehend scientific papers from a variety of disciplines.
4. Ability and efficiency in searching the deeper web.
5. Ability to translate complex scientific ideas and concepts into simple words.
6. Ability to use literary devices - and in TV medium, visual narrative structures.
7. Reasonable understanding of audiences.
8. Ability to adapt to fast changing technologies and techniques of production.
9. A scientific attitude.
10. Reasonably good aesthetic sensibilities.

If the basic aptitudes and attitudes are available, skill building in broadcast production itself is quite easy.

However, most of the students who enroll for courses like Mass Communication, Electronic Journalism, etc., do not have a clear understanding of their own professional calling. They enroll only because of their aspirations – quite often for only the glitter and glamour of broadcast media, mostly for easy, well-paid jobs.

The students' understanding of broadcast media is based on their present habits of media consumption. Even in this information age, the mainstream media does not cover science well and students do not get exposure to good programming in science - except from some foreign channels. So the aspiration to become a science communicator in broadcast media has very little chance to arise.

So the question remains. How do we improve the quantity and quality of science programming in broadcast media?

Evidence based hope

India is far ahead of most Asian countries in terms of science content in broadcast media. While a series like Turning Point was quite natural to Indian television nearly two decades ago, it is only recently that a similar venture was undertaken in ASEAN countries and that too as a collaborative effort between six different countries. An external agency from Germany had to put in effort and money to achieve this. Meanwhile, India has progressed to the stage of tackling science in news format.

Moreover, average Indian broadcast producers are comfortable with asking questions – a characteristic which is needed for good science programmes. This is not the case in most countries in the Asia-Pacific region, where questions are perceived as a sign of mutiny against authority or, worse yet, a sign of ignorance of the questioner. For a questing spirit, cultural, social and psychological barriers are less in India compared to most countries in the region.

In spite of this, we are concerned about the low coverage of science in Indian broadcast media, because of the sheer number of broadcast channels. The diversity of languages used in those channels makes the task even more challenging.

Unfortunately, advances in science are accessible only to people with English language skills. Given the pace of advances in science and technology, and their impact on the lives of the common man, it is important that even the illiterate have adequate knowledge to make informed decisions in their lives. The slow decentralisation of decision making in our democracy makes it imperative that decision makers at the level of Panchayats and in individual households have access to relevant scientific and technological knowledge. This could perhaps be achieved if at least 10 percent of the content in broadcast media relates to science and technology. But how do we get there?

It would be difficult for a science channel to reach across to different linguistic groups in India.

How can we overcome this problem?

Sensible solutions

A three-pronged strategy is proposed here to face the present challenges in science broadcasting.

1. Train radio and television producers to identify and access scientific content relevant to their target audiences, provide tools for dealing with complex scientific content and for converting it into a language comprehensible for target audiences, build skills for structuring and telling it like a story.

2. Train interested researchers, scientists, faculty members and extension educators in the art of communicating using video technologies. Create institutional support systems to facilitate the rapid emergence of scientist broadcasters.

3. Build bridges between media academics and media industries by making the courses relevant to media industries. The focus should be on attitudes, skills and knowledge appropriate to the contemporary media environment.

The *first* strategy would focus on mainstreaming science. Unlike earlier centuries, 21st century science has a lot more studies with implication in areas like sports, economics, politics, music and even religion/spirituality.

Besides using content that is traditionally not considered as a part of science programming, we need to see the variety of genres or forms of broadcast media and see how science can be communicated using genres beyond documentary, interview and magazine formats. Science content in soap operas, music videos etc., has also to be given adequate attention.

Thus the first strategy focuses on generalising or mainstreaming science, in terms of both content and style.

The *second* strategy, however, focusses on specialising. It focusses on a very narrow band of target group of scientists, researchers and teachers – only those who are keen should be trained. Here the focus would not be on content, but on the technology, on the processes of production, on aesthetics and on communication strategies for specific audiences.

The *third* strategy focusses on science journalism courses and mass media/electronic media courses with a science communication paper. To improve the quality and relevance of the courses, the curricula need to be improved.

Practical projects

On the basis of the first two strategies, two workshop curricula were needed. The first one is ready: a five

-day workshop on Broadcasting Science for radio and TV producers. The modules have been tested in Indonesia, Malaysia and Sudan. The first one in the series was conducted in the first week of May 2011 with support from Vigyan Prasar. A few more are in pipeline.

The draft of the second one, a 12-day workshop for scientists, researchers and extension workers is also ready now. A workshop that empowers those who have content to use the technology 1) to document their research (one might skip materials and methods in a journal report, but on video it is exciting viewing); 2) to train students about using complex scientific equipment; and 3) to use in extension education.

Last generation gave us a Prof. Yash Pal, Narlikar, Bala, etc. - scientists and science managers who became communicators. Let us facilitate the development of the next generation of science communicators for the new media environment. Identifying potential science communicators who will adapt easily to soft button technologies and use them with aesthetic sense for telling their stories should keep me occupied for some time.

The third strategy will become easy in execution if NCSTC and UGC agree to co-operate (or UNESCO prompts the Ministry of Human Resources to take cognizance of the curricula developed at an international level). The issue is beyond the scope of this article: it is on science broadcasting, not journalism education.

As happened in the past, will chance bring me the right job to do this task? I am not sure. But it sure looks like I have a lot of work ahead.

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Social Inclusiveness of Indian Science Centres & Museums – A Snapshot through Case Studies (Part II)

Subhabrata Chaudhuri

The educational aspects of science centres and museums have been the subject of numerous studies, while there is much less tangible information on the economic, political or public aspects of these institutions. As a follow-up of accessibility studies in the Part -I of the article, it has been attempted in the Part-II to measure the 'Social Inclusiveness' of a Science centre/museum (including Planetarium, and Natural History Museum), apparently an immeasurable quantity, through statistical interpretations testing the authenticity of the available parameters of the Indian Science centres by direct and indirect methods.

In course of doing so, a set of questionnaire ('Social Inclusion Survey Questionnaire' as attached in Appendix A) is sent to the institutions addressing a number of parameters (statutes), which have already been set as benchmarks of social inclusiveness by different renowned institutions/departments like those of civic bodies in India -Central Public Works Department, Judiciary -framing and executing various laws to combat exclusion, international organizations like UN, Smithsonian Institutions, ICOM etc.

Underlying Philosophy of the Study

Background of the Main Survey

This survey is designed to judge in two stages the inclusiveness of the centre by the means of visitor turnout in terms of participation of different strata of the society to Science Centre activities, social activity orientation i.e.how the centre is addressing different social classes and other parameters like fee structure (in an attempt to make a measure of the magnitude of financial inclusiveness of such institutions), publicity budget (to measure the institutional initiatives towards social inclusion) etc.

Aim of the Analysis

For a Science Centre / Museum or rather for any cultural institution in India reaching out to the multifold society is the biggest of all the issues. The objective of this elaborate study is to test the 'Social Inclusiveness' of the Indian Science Centres, in the light of various rationales. However, it is to be kept under consideration that in context of Indian Science Centres and Museums, complex multifold social issue like social inclusion cannot properly be understood just by some numerical figures and statistical simulations that use figures related to visitor turnout and outreach programmes or social activities as the base data.

Fundamental Analysis of the Data

We'll use simple fundamental statistical analysis on the basis of the collected data through graphical / thematic interpretations. Based on these interpretations, an attempt has been made to analyse the inclusive characteristics of the Indian Science centres.

Name of the Participating Indian Science Centres, Museums & Planetaria

APSC:	Arunachal Pradesh Science Centre
BMPIL:	Birla Museum, Pilani
BITM:	Birla Industrial & Technological Museum
DSCDGA:	Digha Science Centre & National Science Camp
DSCDHAR:	District Science Centre, Dharampur
DSCDKL:	Dhenkanal Science Centre
DSCGUL:	District Science Centre, Gulbarga
MANSC:	Manipur Science Centre (Department of Science & Technology, Govt. of Manipur)
DSCPURU:	District Science Centre, Purulia
DSCTIRU:	District Science Centre, Tirunelveli
GUWPLA:	Guwahati Planetarium
GSC:	Goa Science Centre
KPSC:	Kurukshetra Panorama & Science Centre
MIZOSC:	Mizoram Science Centre
MSPSSC:	Meghnad Saha Planetarium & Space Science Centre
NAGSC:	Nagaland Science Centre
NBSC:	North Bengal Science Centre
NSCD:	National Science Centre, Delhi
NSCM:	Nehru Science Centre, Mumbai
PSPBBSR:	Pathani Samanta Planetarium, Bhubaneswar
PGSC:	Pushpa Gujral Science City
RMNHBBSR:	Regional Museum of Natural History, Bhubaneswar
RMNHBHO:	Regional Museum of Natural History, Bhopal
RSCBHO:	Regional Science Centre, Bhopal
RSCBBSR:	Regional Science Centre, Bhubaneswar
RSCCALI:	Regional Science Centre &Planetarium, Calicut
RSCG:	Regional Science Centre, Guwahati
RSCL:	Regional Science City, Lucknow
RSCNAG:	Raman Science Centre & Planetarium, Nagpur
RSCT:	Regional Science Centre, Tirupati
SCBUR:	Science Centre, Burdwan
SCPB:	Science Centre, Port Blair
SCSOLA:	Sholapur Science Centre
SCTY:	Science City, Kolkata
SHISC:	Shillong Science Centre, Meghalaya
SSC:	Sikkim Science Centre
SSCP:	Shrikrishna Science Centre, Patna
SUKACK:	Sukanta Academy, Agartala
TNSTC:	Tamilnadu Science & Technology Centre
VITM:	Visvesvaraya Industrial &Technological Museum

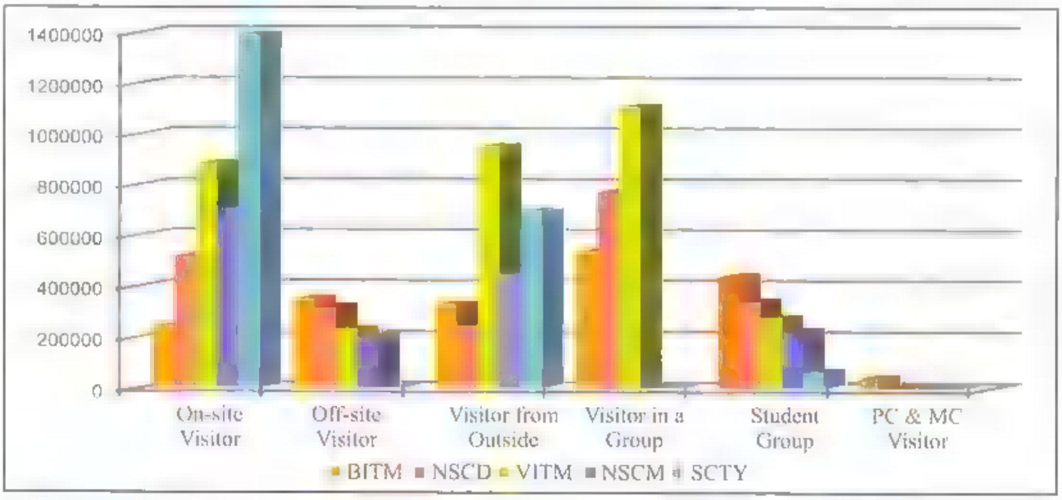

Chart 1 **(Data: 2009-2010)**

Analysis of the visitor figure of the National level Science Centres.

Considering the visitor statistics of five National level centres of NCSM

* It is observed that Science City has the largest on-site visitor turnout (about 1400000) and the BITM, Kolkata has the lowest.
* Mainly the outreach programmes like MSE, science fairs etc. are sources of off-site visitors. In this segment, BITM and NSCD are far ahead of their nearer counterparts VITM and NSCM.
* Visitor base of NSCD is mostly local whereas VITM, Bangalore has got the highest number of outside visitors and Science city is not far behind of VITM in getting outside visitors.
* NSCM & Science City could not provide the exact figures in respect of physically challenged (PC) & mentally challenged (MC) visitors and also those of group visits; however, amongst the others VITM received the maximum number of group visitors.
* BITM, Kolkata outperformed others in reaching out to the student groups. Though Science city has the largest visitor turnout figure, student groups do not visit much.
* Except BITM, NSCD and VITM, the other two National level centres fail to provide the visitor dataregarding the physically and mentally challenged segment groups. Because of the exhibition on 'World in Darkness' (a gallery for visually impaired groups) and also due to some other reasons, BITM got largest number of PC & MC visitors during 2009-10.

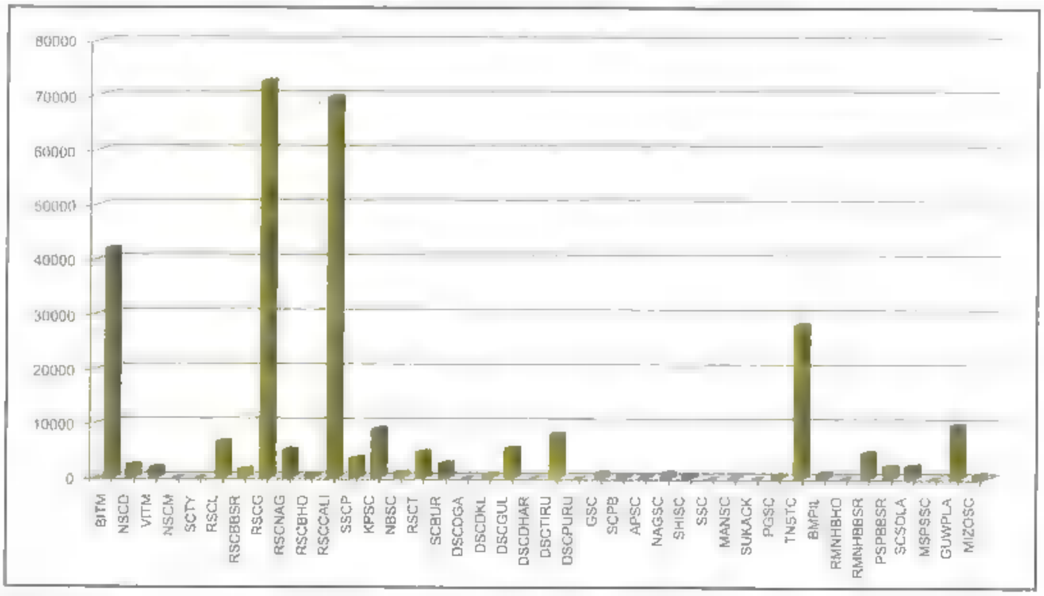

Chart 2

Analysis of figures of physically and mentally challenged visitors in all the centres surveyed

The above chart represents the visitor turnout pattern of the number of physically and mentally challenged visitors in the science centres, museums, natural history museums and planetariums surveyed.

* It is evident from the above that RSCG has received the highest number (more than 70,000) of physically and mentally challenged visitors, whereas RSCCALI is also closely following (about 70,000). BITM received more than 40,000 of physically and mentally challenged visitors.
* Outside NCSM network, TNSTC, RMNHBBSR and GUWPLA have received a significant number of physically and mentally challenged visitors.

All collected samples are not included in this analysis as representative random data is required and some of the data are found to be incomplete.

* Here it may be noticed that in most of the cases the regional and district science centres more or less operate with the local visitors.
* All over the world 'Bringing student groups in the science centre' is regarded as one of the yardsticks of successful social inclusion measure for science centres. Under this, RSCCALI is emerging as a leading institution among the above studied samples.
* Moreover, we must take into note that with respect to the total visitor count, the centres situated in the southern part of the country showed better performance than their northern counterparts, in bringing organized student groups in their respective centres.

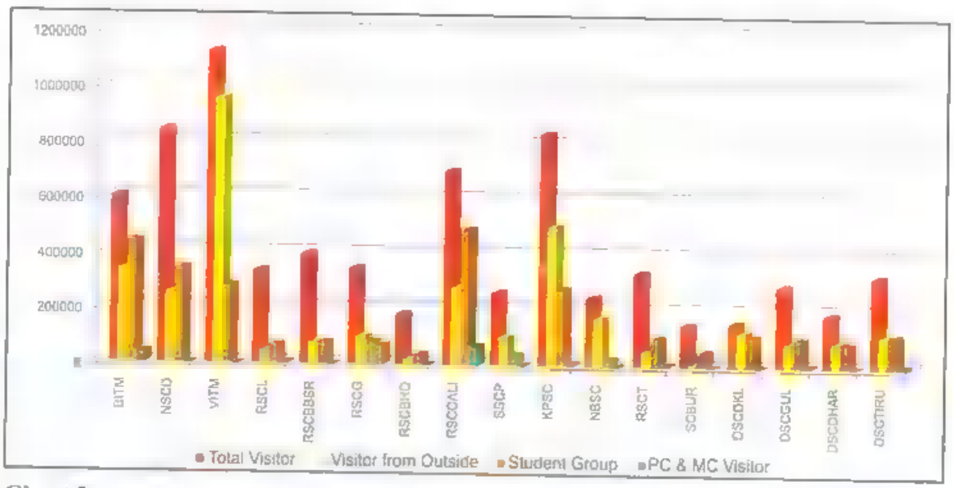

Chart 3

Distribution of the Visitors in National, Regional & District level Science Centres.

* Not only that regional level science centres are better performers in bringing physically and mentally challenged visitors into their centres.

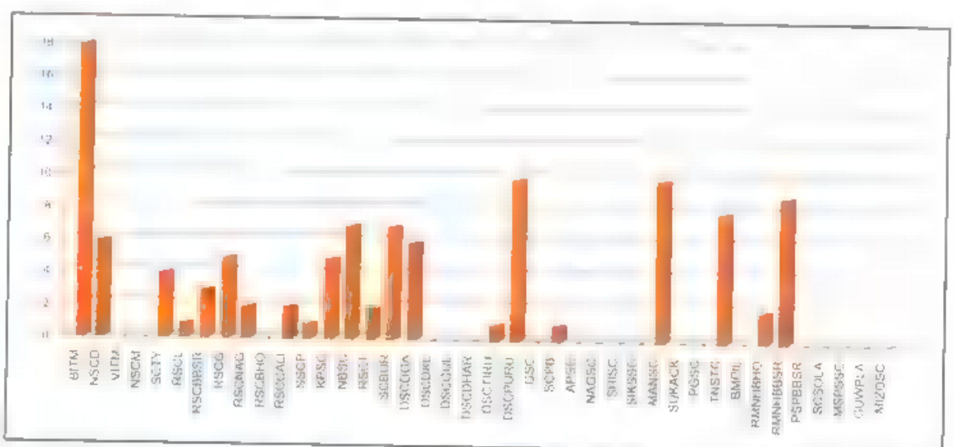

Chart 4

Programmes for Groups with Special Needs

Conducting programmes for groups with special needs is regarded as an important social inclusion initiative for science centres/museums etc.

* In last 5 years BITM, Kolkata has conducted highest number of programmes (about 18 nos) for groups with special needs and 6341 participants participated in these programmes.
* Besides BITM, NSCD and SCTY are the two national level science centres which conducted a number of programmes for groups with special needs in the last five years.
* Regional and District Science Centres have done well in organizing programmes for groups with special needs. As evident from the collected data, DSCPURU conducted maximum number of such programmes followed by SCBUR, NBSC, Siliguri; DSCDGA, RSCG, KPSC, RSCs at Nagpur, Bhubaneswar Calicut, Tirupati and Lucknow, SSCP and DSCTIRU.
* Outside the NCSM network, MANSC, TNSTC, RMNH at Bhubaneswar and Bhopal conducted a number of programmes for people with special needs.

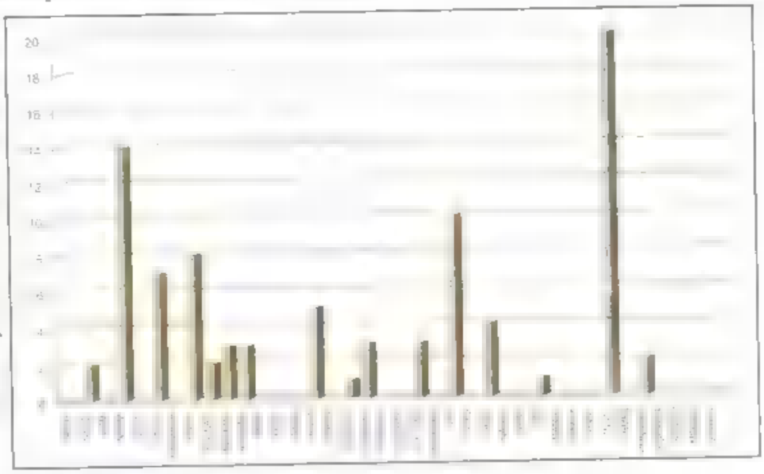

Chart 5

Programmes for Senior Citizens & Women.

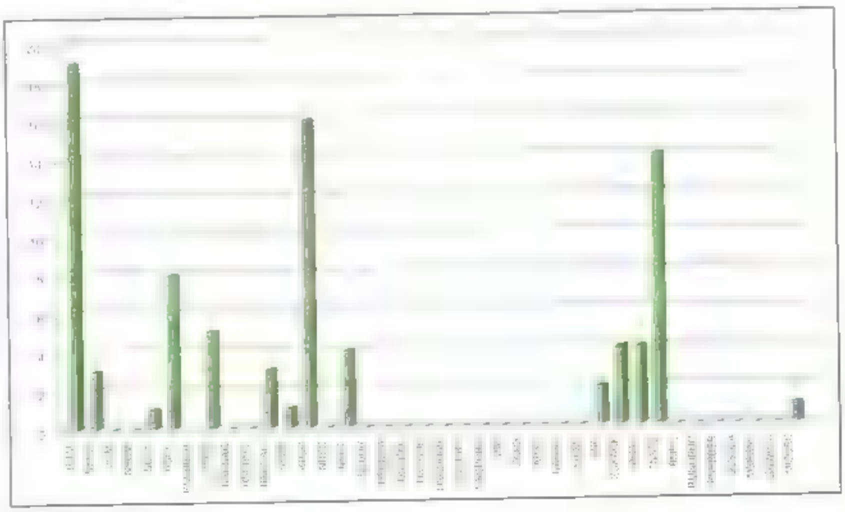

Chart 6

Engaging Senior citizens and women by science centres through different activities is a sign of inclusiveness for the centre.

* Most of the NCSM centres conduct programmes for senior citizens and women. Among all NCSM centres, NSC, Mumbai conducts maximum number of programmes for this particular group followed by GSC, RSCG, RSC, Tirupati etc.
* Among the non-NCSM centres, TNSTC conducts maximum number of programmes for this group. It is the most active centre in this segment amongst the centres surveyed.

Programmes for Personal Growth.

Enhancing personal quality of the citizens is regarded as one of the important steps of a science centre/museum towards the social inclusion.

* In this segment BITM, Kolkata is leader, followed by KPSC, RSCL, RSCG, RSCT, etc.
* Outside the NCSM network, TNSTC is the most active in doing programmes towards social inclusion, followed by PGSC and SUKACK.

the steps of a science centre/museum towards social inclusion.

* In this segment, RSCBHO is way ahead of its nearer competitor DSCGUL followed by DSCDHAR, RSCL and BITM, Kolkata etc.
* Outside NCSM network, SUKACK has performed significantly in this segment in the last few years.

However, it seems that there is some data incompatibility in respect of DSCTIRU which is said to be conducting good numbers of community empowerment programmes.

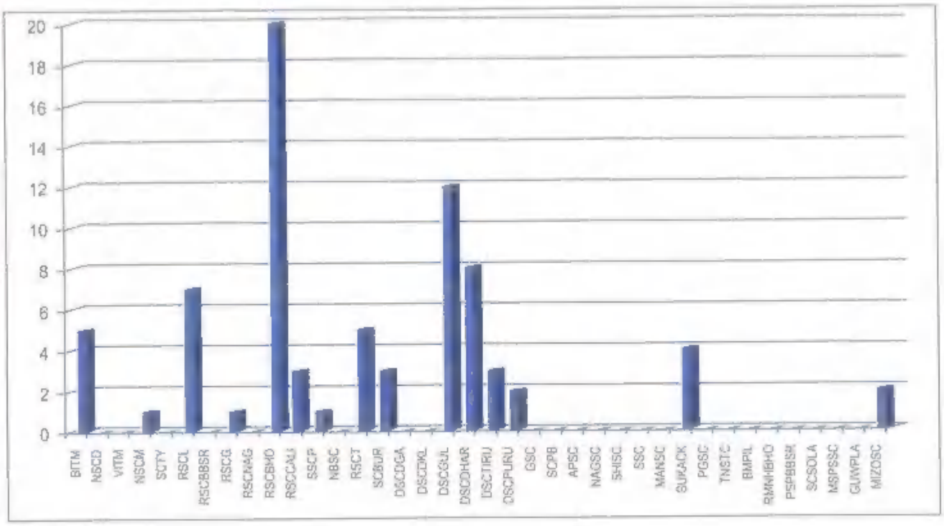

Chart 7

Programmes for Community Empowerment.

Conducting programmes for community empowerment or making healthier community is one of

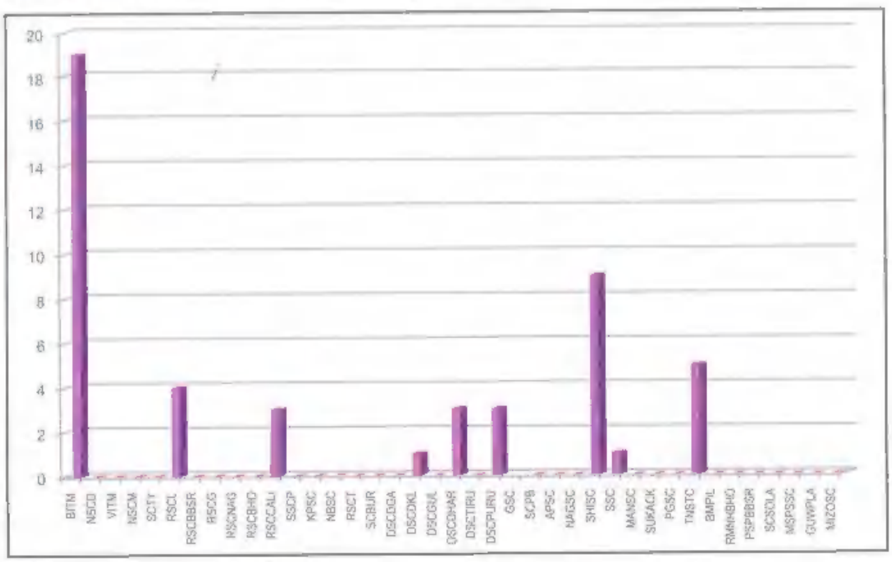

Chart 8

Programmes for Tackling Unemployment

Step towards solving the problem of unemployment is another aspect of social inclusiveness of a science cenetre/museum.

* Among all, BITM, Kolkata has taken a lot of steps towards solving this social problem followed by RSCL, RSCCALI, DSCDHAR, DSCPURU etc.
* Outside NCSM network, SHISC and TNSTC have already taken steps in addressing this issue.

> *As communicated, a programme was conducted in the year 2002 at DSCDKL on motor rewinding. After undergoing training in the said programme, two students have started their own workshops and are now earning their livelihood.*

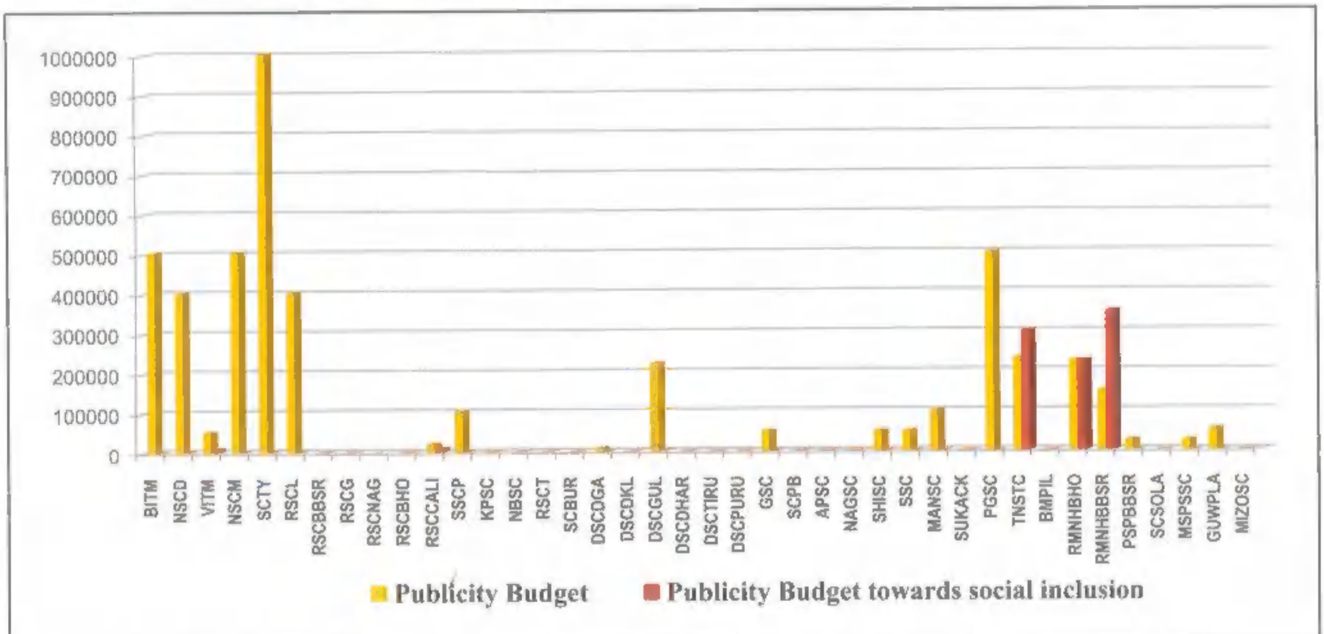

Chart 8

Publicity Budget – an initiative towards social inclusion towards social inclusion.

Publicity Budget (and publicity budget for social inclusion) is regarded as an initiative for a science centre to be socially inclusive.

* Science City has the largest allocation towards publicity among the entire group of science centres surveyed. It is followed up by NSCM, BITM, Kolkata, NSCD, RSCL, etc. In fact among all these NCSM centres VITM, Bangalore and RSCCALI have separate publicity budget for social inclusion.
* Outside NCSM centres, PGSC has the largest budgetary allocation for publicity, but RMNHBBSR, followed up by TNSTC, have got separate social inclusion publicity budget.

1) Science City, Kolkata – Rs. 10,00,000.00 (No separate budget for measures towards social inclusion)
2) NSCM – Rs. 5,00,000.00 (No separate budget for measures towards social inclusion)
3) BITM – Rs. 5,00,000.00 (No separate budget for measures towards social inclusion)
4) TNSTC – Rs. 2,31,000.00 (Special Budget for social inclusion 3 lakh)
5) RMNH, BBSR – Rs. 1,50,000.00 (Special Budget for social inclusion 3.5 lakh)

Critical Analysis for Critical Groups (from the data collected)

In course of building a confidence interval indicating the inclusive attendance of the physically and mentally challenged visitors in Indian science centres/museums (based on the surveyed data).

Name of the Centre	PC* & MC** Visitor
BITM	42105
NSCD	2528
VITM	2252
NSCM	1185
SCTY	496
RSCL	6723
RSCBBSR	1794
RSCG	72820
RSCNAG	5445
RSCBHO	912
RSCCALI	70000
SSCP	3930
KPSC	9202
NBSC	1265
RSCT	5055
SCBUR	3053
DSCDGA	NA
DSCDKL	804
DSCGUL	5867
DSCDHAR	14
DSCTIRU	8250
DSCPURU	NA
GSC	1176
SCPB	608
APSC	349
NAGSC	1200
SHISC	862
SSC	NA
MANSC	340
SUKACK	NA
PGSC	750
TNSTC	28426
BMPIL	1200
RMNHBHO	NA
RMNHBBSR	5004
PSPBBSR	2600
SCSOLA	2534
MSPSSC	NA
GUWPLA	10134
MIZOSC	946

Table 1.

Mean (m)	7496
SD (σ)	16807

Significance level	0.01	0.05
Standard deviation of the population	16807	16807
Sample size	40	40
Confidence interval for population mean	±6845.1	±5212.2

Table 1.1

To find the Confidence Intervals for 1% and 5% significance level for the (Population) mean,

Collected data with Mean 7496 and Standard Deviation of 16807,

We can choose the statistics

$u = \sqrt{n}(\bar{x} - m)/\sigma$

whose sample distribution is assumed to be normal (0,1) and which depends on m, the parameter to be estimated.

Taking two points $\pm u_\alpha$ symmetrically about the origin such that

$P(-u_\alpha < U < u_\alpha) = 1 - \alpha$

or, $P(-u_\alpha < \sqrt{n}(\bar{X} - m)/\sigma < u_\alpha) = 1 - \alpha$

may be written as

$P(\bar{X} - \sigma u_\alpha/\sqrt{n} < m < \bar{X} + \sigma u_\alpha/\sqrt{n}) = 1 - \alpha$

Hence a confidence interval for m having confidence coefficient $1 - \alpha$ is $(\bar{x} - \sigma u_\alpha/\sqrt{n},\ \bar{x} + \sigma u_\alpha/\sqrt{n})$

We find that, in our sample of 40 science centres/museums/planetaria, the average turnout of physically and mentally challenged visitor is 7496 with a population standard deviation of 16807.

Case – I

With alpha = 0.05, CONFIDENCE (0.05, 16807, 40) returns 5212.2 (~5212).

The corresponding confidence interval is

then 7496 ± 5212 = approximately [2284, 12708].

We observe from the above table that RSC, Guwahati (72820), Calicut (70000) and BITM (42105) are way ahead of others in getting physically and mentally challenged visitors.

But based on the above 5% confidence interval (mainly considering the lower bound) about the mean of this special group of visitors (physically and mentally challenged) figure (where standard deviation is known), we may conclude that –

a) Though the PC & MC visitor figure seems to be very low for NSCD (2528), SCSOLA (2534), PSPBBSR (2600), SSCP (3930) and SCBUR (3053) but they are still inclusive in nature.

b) DSCDHAR (14), MANSC (340), APSC (349), SCTY (496), SCPB (608), PGSC (750), DSCDKL (804), SHISC (862), RSCBHO (912), MIZOSC (946), NBSC (1265), GSC (1176), NAGSC (1200), BMPIL (1200) and VITM, Bangalore (2252), are the centres which need to work towards the direction, so to increase the visitation of this special group (physically and mentally challenged) to their respective centres.

c) Rest of the science centres/museums and planetaria seem to be socially inclusive against the above set standard.

[We exclude those centres which have indicated visitor figure as nil due to the reason that they either didn't maintain their data properly or weren't able to provide the consistent data.]

Case – II

With alpha = .01, CONFIDENCE (.01, 16807, 40) returns 6845.1(~6845).

Based on the above 1% confidence interval (mainly considering the lower bound) about the mean of this special group of visitors (physically and mentally challenged) figure (where standard deviation is known), we may conclude that –

Most of the surveyed centres have inclusive special group visitor figures (physically and mentally challenged) except a few like MANSC (340) and SCTY, Kolkata (496).

In order to test the Social Inclusiveness of Indian science centres/museums, planetaria and natural history museums for the special group visitors (physically and mentally challenged), we further extended our study in a comprehensive way to arrive at a definite conclusion.

Following is the methodology of this further study:

* We collected the Total population data of the Indian states, the state wise 'Disable Population' and the Local population data from census 2001. In course of calculating the local disable population, we assume that % of disable population is 'homogeneous' in the state.
* From the questionnaire survey as received from 40 centres, we have the number of physically and mentally challenged visitors to the centres.
* We will find the % of physically and mentally challenged visitors against local population and against the total visitors of the centre. If these figures seem to be compatible in nature then we declare the centre to be inclusive.

So we need the following for the thematic study:

1) Local population (where the science centre is situated),
2) Percentage of disable population in local group and
3) Number of special group visitors in the centres.